1954.
(Twenty-first Parliament.)

THE PARLIAMENT OF THE COMMONWEALTH OF AUSTRALIA.

SIXTH ANNUAL REPORT

OF THE

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

FOR THE

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6 SEP 1955

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COMMONWEALTH OF AUSTRALIA.

Commonwealth Scientific and Industrial Research Organization.

SIXTH ANNUAL REPORT FOR THE YEAR ENDING 30TH JUNE, 1954.

I. INTRODUCTORY.

1. GENERAL.

The Commonwealth Scientific and Industrial Research Organization was established on 19th May, 1949, when the *Science and Industry Research Act* 1949 was proclaimed. Under that Act the Organization took the place of the Council for Scientific and Industrial Research, which in turn had, in 1926, taken the place of the Institute of Science and Industry.

The powers and functions of the Organization are similar to those of the former Council and include the initiation and carrying out of research in connexion with, or for the promotion of, primary and secondary industries in the Commonwealth or any Territory of the Commonwealth, or in connexion with any matter referred to the Organization by the Minister; the training of research workers; the making of grants in aid of pure scientific research; the testing and standardization of scientific apparatus and instruments, and the carrying out of scientific investigations connected with standardization; the collection and dissemination of information relating to scientific and technical matters; and acting as a means of liaison with other countries in matters of scientific research.

2. EXECUTIVE.

Dr. S. H. Bastow, D.S.O., B.Sc., Ph.D., has been re-appointed as a member of the Executive for a further period of five years.

3. ADVISORY COUNCIL.

Mr. D. R. Hawkes, of "Moorara", Naracoorte, South Australia, has been co-opted to the Advisory Council to fill the vacancy caused by the retirement of Mr. W. S. Kelly.

4. SECRETARIAT.

Following upon the secondment of Mr. W. Ives to London for a period of two years to take charge of the Australian Scientific Liaison Office, the following arrangements have been made in the duties of the Secretariat:—

- Mr. G. B. Gresford, Secretary (Industrial and Physical Sciences) is also Acting Secretary (Agricultural and Biological Sciences).
- Mr. P. F. Butler has been designated Assistant Secretary (Agricultural and Biological Sciences).

5. RETIREMENT OF DR. L. B. BULL.

Dr. L. B. Bull, C.B.E., D.V.Sc., the Organization's most senior Chief of Division, retired at the end of June, 1954, as Chief of the Division of Animal Health and Production.

Dr. Bull will not be severing his connexion with the Organization, having accepted a Senior Research Fellowship to continue his researches at the Division of Animal Health and Production in the field of animal pathology.

Dr. Bull has been succeeded as Chief of the Division of Animal Health and Production by Mr. D. A. Gill, M.R.C.V.S., D.V.S.M., formerly Assistant Chief of the Division and Officer in charge of the McMaster Animal Health Laboratory, Sydney.

Mr. Gill has been succeeded as Officer in charge of the McMaster Laboratory by Dr. D. F. Stewart, D.V.Sc., Dip.Bact.

Dr. T. S. Gregory, D.V.Sc., Dip.Bact., has become Officer in charge of the Division's Animal Health Laboratory at Parkville (Melbourne).

6. HONOURS AND AWARDS.

Sir Ian Clunies Ross, the Chairman of the Organization, was twice honoured by the Queen during the year under review. In the New Year Honours he was made a Companion of the Order of St. Michael and St. George in recognition of his distinguished public service in scientific research for the promotion and improvement of the primary and secondary industries. In the Queen's Birthday Honours he was made a Knight Bachelor for his outstanding contribution to science in Australia.

Dr. F. W. G. White, the Chief Executive Officer, was made a Commander of the Order of the British Empire for his services as Chief Executive Officer of the Organization, particularly for his contributions to the development of radiophysics in Australia.

Mr. H. J. Goodes, a member of the Executive, and Assistant Secretary to the Commonwealth Department of the Treasury, was made an Officer of the Order of the British Empire in recognition of his distinguished work in the Commonwealth Public Service.

Dr. F. L. Stillwell, formerly Officer in charge of the Mineragraphic Investigations Unit, was made an Officer of the Order of the British Empire for his outstanding contributions to research for the Australian mining industry.

Dr. R. B. Kelley, formerly Assistant Chief of the Division of Animal Health and Production, was made an Officer of the Order of the British Empire for his outstanding service in beef and dairy cattle improvement in the north of Australia.

Dr. J. L. Pawsey, Assistant Chief of the Division of Radiophysics, has been elected a Fellow of the Royal Society of London, in recognition of his distinguished contributions to the science of radio and radar, and in particular for his application of these techniques to radio astronomy and to the study of the ionosphere. He was also awarded the Thomas Rankin Lyle Medal by the Australian National Research Council for outstanding research in Australia in mathematics and physics during the past five years.

The following officers of the Organization have been elected as Fellows of the newly formed Australian Academy of Science:—Sir Ian Clunies Ross, Dr. W. Boas, Dr. L. B. Bull, Dr. E. A. Cornish, Dr. O. H. Frankel, Mr. H. R. Marston, Dr. D. F. Martyn, Dr. A. J. Nicholson, Dr. J. L. Pawsey, Dr. C. H. B. Priestley, Dr. A. L. G. Rees, Dr. R. N. Robertson, Dr. A. W. Turner, Dr. I. W. Wark, Dr. D. F. Waterhouse.

Sir Ian Clunies Ross was awarded the Kendall Medal on the occasion of his delivering the Kendall Oration at the Conference of the Australian and New Zealand Association for the Advancement of Science, in Canberra.

Sir Ian Clunies Ross and Dr. L. B. Bull were awarded Honorary Associateships of the Royal College of Veterinary Surgeons, London, in recognition of their contirbutions in the field of veterinary science.

Sir David Rivett, Chairman of the former Council for Scientific and Industrial Research, was awarded the James Cook Medal by the Royal Society of New South Wales for his outstanding contributions to science and human welfare in and for the southern hemisphere.

The Royal Society of New South Wales awarded the Clarke Medal for 1953 to Dr. A. J. Nicholson, Chief of the Division of Entomology, in recognition of his contribution to the knowledge of Australian insects.

Mr. G. Loftos Hills, Officer in charge of the Dairy Research Section, was given the 1954 Gold Medal Award by the Australian Society of Dairy Technology, in recognition of his outstanding work for the dairy industry in Australia.

Dr. D. F. Waterhouse, Assistant Chief of the Division of Entomology, was awarded the Melbourne University's David Syme Research Prize for 1953 in association with Dr. F. P. Dwyer of the Chemistry Department, University of Sydney, for studies of the digestive process of insects.

Dr. J. Morrison, Senior Research Officer, Division of Industrial Chemistry, was awarded the 1953 Rennie Memorial Medal by the Royal Australian Chemical Institute, for the year's best contribution to the development of chemical science in Australia.

7. First William McIlrath Fellow.

Following upon the gift made to the Organization last year by Mr. William McIlrath for the establishment of a Senior Research Fellowship, Dr. M. C. Franklin, of the McMaster Animal Health Laboratory in Sydney, has been appointed as the first William McIlrath Fellow.

In co-operation with the Dean of the Faculty of Veterinary Science of the University of Sydney and the Chief of the Division of Animal Health and Production, he is initiating a programme of research on animal husbandry with special reference to the beef cattle industry.

8. New Division.

The Section of Mathematical Statistics, with headquarters in Adelaide, has been designated a Division, and Dr. E. A. Cornish Chief of the Division.

9. Buildings and Accommodation.

During the year the Organization took possession of the following buildings, some of which have been under construction for many years:—The new laboratory block for the Division of Tribophysics in the grounds of the University of Melbourne; the Biochemstry Laboratory for the Division of Industrial Chemistry in Melbourne; the new building for the Geelong unit of the Wool Textile Research Laboratories at Belmont, Victoria; a new prefabricated Hawksley building as the first stage of accommodation for the Section of Meteorological Physics at Aspendale, Victoria; and a small prefabricated aluminium laboratory on the Katherine Research Station.

Work is still in progress on the buildings of the Sheep Biology Laboratory at Prospect, New South Wales; the Central Block and the Microbiological Laboratory, Canberra; the Perth Regional Laboratory; and the Dairy Research Laboratory at Highett, Victoria.

Work has also commenced on a laboratory and workshop building for the Biochemistry Unit of the Wool Textile Laboratories at Parkville, Victoria.

10. Overseas Visitors.

A number of leading scientists from overseas visited Australia in the year under review, many of them under the auspices of the Organization. In their visits to laboratories and establishments, they gave much stimulus and help to Australian research workers.

Mr. Wendell Mordy, the Head of the Meteorology Department of the Sugar and Pineapple Research Institute in Honolulu, spent two months collaborating with officers of the Division of Radiophysics in work on cloud and rain physics.

Professor F. M. Hull, Professor of Biology at the University of Mississippi, United States of America, spent some months at the Division of Entomology under a research grant from the United States National Science Foundation and was engaged on a monograph on Diptera.

Professor R. E. Glover, B.Sc. (Lond.), M.A. (Cantab.), F.R.C.V.S., Professor of Veterinary Pathology at the University of Liverpool and President of the Royal College of Veterinary Surgeons in the United Kingdom, made a short tour of Australia and gave a series of both public and specialist lectures.

Dr. E. Y. Hosaka, B.S., M.S., a specialist in pasture management from the University of Hawaii, Honolulu, collaborated with officers of the Division of Plant Industry, devoting special attention to problems of pasture development in tropical and sub-tropical areas. His visit was made possible by a grant from the Rural Credits Development Fund of the Commonwealth Bank of Australia.

Dr. Raimon Beard, a leading insect pathologist of the Connecticut Agricultural Experiment Station, United States of America, worked with the Division of Entomology under a Fulbright Award, investigating bacterial diseases of larvae of cockchafer beetles.

Professor H. J. Emeléus, M.A., D.Sc., F.R.S., Professor of Inorganic Chemistry of the University of Cambridge, spent three months travelling in all States and lecturing on aspects of recent progress in inorganic chemical research.

Professor O. Struve, Professor of Astrophysics at the University of California and President of the International Astronomical Union, spent a month collaborating with officers of the Division of Radiophysics on investigations in the field of astrophysics.

11. Transfer of Atomic Physics Research.

The Australian Atomic Energy Commission has now taken over the work of the Atomic Physics Investigations Unit under the direction of Professor L. H. Martin at the University of Melbourne, and also that of the Organization's officers working at the Atomic Energy Research Establishment, Harwell, England.

12. Geelong Grammar School Bursaries.

In recognition of the contribution made by the Organization to the grazing and other industries, the Council of the Geelong Church of England Grammar School, Corio, Victoria, has made available two bursaries for sons of officers of the Organization. The bursaries are to be available for ten years following and including 1954, after which time their availability may be reconsidered by the School Council.

The bursaries have now been awarded to Hugh McL. Gordon, the son of Mr. H. McL. Gordon, Principal Research Officer, Division of Animal Health and Production, and to William Quinlan-Watson, the son of Mr. T. A. Quinlan-Watson, Senior Research Officer, Division of Biochemistry and General Nutrition.

The Executive is gratified at this signal recognition, in such a practical form, of the work of the Organization.

13. Research Staff.

In the last Report attention was drawn to the present-day difficulties in attracting first-class men to research careers in science, and it was pointed out that for the well-being of the Organization it was necessary to obtain a substantial proportion of the best graduates from Australian universities as well as a number of highly trained men from overseas. The position during the last year has become markedly worse, and is in fact quite alarming. At the beginning of the year vacancies existed for 112 Research Officers, for which the minimum requirement is a good honours degree. The year ended with a net gain of only three. Recruitment of Technical Officers, for which qualifications are not quite so stringent, has been satisfactory. It is quite apparent that there is a widespread shortage of really good honours men.

There is, of course, increasing competition for such graduates from other government departments, from industry, and from universities, but these bodies also are finding it difficult to attract highly qualified men. Concerted efforts have been made to recruit research officers from overseas, mainly the United Kingdom, but despite what were in effect personal recruiting drives by senior officers in the United Kingdom, the Continent, and America, the result has been most disappointing. The prospects offered to a young man in scientific research in Australia are apparently not attractive enough to draw him from England, still less from America. Recruitment of agricultural scientists from Holland has met with only limited success.

The Executive has been able to effect some improvement within the range of promotion of its own officers, but it is of course limited by the framework imposed by the Act. The Executive believes, however, that the problem is a national one, and that if Australia is to have an adequate supply of specialists and highly qualified professional scientific men, both in public and private employment, it is a matter of great urgency that the prospects open in such careers should be very greatly improved.

14. Overseas Visits, Fellowships, and Studentships.

As in previous years, a number of officers of the Organization were sent overseas for periods ranging from two to twelve months to acquire experience and training in new techniques, and to collect general information on developments in scientific research. Two officers were sent overseas primarily to attend important international conferences, and in addition two senior officers were invited to visit overseas institutions for consultations concerning special aspects of their work.

The policy of awarding overseas studentships for research in specific fields was continued, and seven studentships were awarded. Seven traineeships were also awarded, conditions being very similar to those pertaining to studentships. One studentship was awarded from the Science and Industry Endowment Fund. At the close of the year, 30 overseas studentships and traineeships were current.

Twelve studentships were awarded early in 1954 for post-graduate work in Australian universities, raising the total of those receiving training under this scheme to 22. During the year, three students who received Australian studentships in 1952 successfully completed their studies.

A chemist who was awarded a Textile Research Fellowship for training overseas in chemical problems related to the wool industry returned to Australia. A second Textile Research Fellowship has recently been awarded to an engineer for training overseas.

15. Co-operative Research with Industry.

Support for the Australian Leather Research Association and the Bread Research Institute of Australia has been continued under arrangements similar to those existing in Great Britain between the research associations and the Department of Scientific and Industrial Research. Both these associations are now well established and making valuable contributions to their respective industries. Conversations are being held with several other industrial groups about the possibility of setting up additional research associations.

Several of the Organization's laboratories are undertaking specific research projects on behalf of industry.

16. Collaboration with Universities.

The Organization's work in the universities is mentioned in various places in the main body of the Report. During the year under review there has been some extension of collaborative research arrangements with universities. The Organization recognizes the great importance of such arrangements in stimulating its work and gratefully acknowledges its debt to the universities.

17. Farm Mechanization Research.

The Advisory Council at its meeting in November, 1952, stressed the material importance of mechanizing farm production in Australia to the greatest possible degree, and suggested that the Executive should look closely at this matter to determine whether there was scope for a research programme which might be undertaken by the Organization.

With this end in view, the Executive has selected fodder conservation as a typical phase of primary production, and its arranging for a survey of the actual operations of conserving grass hay on farms in order to define the problem and clarify the nature of any research required. On this basis it should be possible to determine what part might be played by the Organization in this field.

Arrangements were made for this work to be undertaken by the University of Melbourne, with finance provided by the Rural Credits Development Fund of the Commonwealth Bank of Australia. Observations were made in the dairying districts of Victoria during the summer 1953-54 and the research team, comprising an engineering and an agricultural science graduate, will complete this survey stage of the project during the 1954-55 season. Besides examination of the processes in the field, more detailed engineering research on the mower and rake will be conducted on selected properties in collaboration with the Organization's Plant Fibre Section.

The Organization has also arranged for a grant from the same source to be made to the New South Wales University of Technology for work to be undertaken by the School of Mechanical Engineering on the shape and development of hard-working surfaces on scarifier shares.

18. Science and Industry Endowment Fund.

During the year, the Executive, as Trustees of the Science and Industry Endowment Fund, approved grants to assist research workers as follows:—Dr. E. J. Reye, for work on sandflies; Mr. Tarlton Rayment, for taxonomic work on bees; Mr. L. Symons, for parasitological research; Dr. I. Cookson, as a contribution toward expenses involved in attending the Eighth International Botanical Congress in Paris, and in subsequent study overseas; Dr. B. Breyer, for polarographic studies; Dr. J. Pearson, for work on the comparative anatomy and embryology of marsupials; Mr. A. W. Parrott, for taxonomic work on parasitic wasps; Dr. C. J. Magee, as a contribution towards attendance at the Fifth Mycological Conference at London; Mr. B. C. Cotton, Conchologist at the South Australian Museum, for study expenses while overseas; Mr. C. Laseron, for palaeontological work in New South Wales; Mr. H. Womersley, for acarological studies; and Dr. M. Clynes, for investigating methods of surface finishing.

In addition, a studentship for overseas training in biophysics was awarded to Mr. F. F. Denby.

19. FINANCE.

Chapter XXXV. gives details of the expenditure incurred during 1953-54 by the Organization from all funds at its disposal, totalling £4,861,873. The major portion of this sum was derived from the Commonwealth Treasury—£3,615,121 expended in connexion with normal research activities, £98,271 on grants to bodies such as the Commonwealth Agricultural Bureaux, and £1,963 on capital works under the control of the Organization. The remainder was expended on investigations financed from contributions, viz.: £569,038 from the Wool Research Trust Account, £372,399 from the Wool Industry Fund, and £205,081 from grants including special revenue. Certain other expenditure was incurred by the Commonwealth Department of Works, on building projects for the Organization from funds controlled by that Department. Likewise the Department of the Interior met the costs of rentals and acquisition of sites and buildings for the Organization from funds made available to that Department by the Treasury.

The Organization is particularly gratified by the way in which various bodies continue to support it, and by the marked interest evinced by certain sections of industry which have provided donations for cooperative research. Among the many contributions received, reference may be made to those of the Commonwealth Bank of Australia (through the Rural Credits Development Fund), Australian Wool Board, Australian Meat Board, Australian Dairy Produce Board, Australian Wine Board, Australian Egg Board, the Queensland Meat Industry Board, the New South Wales Department of Agriculture and New South Wales Water Conservation and Irrigation Commission, the Metropolitan Meat Industry Commissioners of New South Wales, the George Aitken Pastoral Research Trust, Burdekin Bequest, and Alexander Fraser Memorial Fund, the Dried Fruits Control Board, the Australian Dried Fruits Association, and the dried fruits industry, the National Gas Association, Australasian Institute of Mining and Metallurgy, Australian Cement Manufacturers' Association, the wool textile industry, the timber industry, and the pulp and paper industry.

20. ORGANIZATION.

For the purpose of carrying out its research work, the Organization has established a number of Divisions and Sections. The Divisions, of which there are now sixteen, comprise the major establishments, which may be further subdivided into Sections; there are also eighteen independent Sections comprising establishments which have not reached a stage of development, so far as the scope and magnitude of their operations are concerned, to justify their designation as Divisions.

In the present Report an attempt has been made to group the material according to its subject matter rather than according to the Division or Section concerned. Additional chapters and appropriate cross references have been inserted, however, to permit the work of any particular Division to be reviewed as a whole.

As the Organization's investigations extend on a Commonwealth-wide basis and as many of the investigations which are being conducted—particularly those concerned with problems affecting the agricultural and pastoral industries—necessitate experimental work in the field, a number of branch laboratories and field stations have been established in various parts of Australia.

The Head Office of the Organization is in Melbourne and associated with it are the Organization's Central Library, Agricultural Research Liaison Section, and Central Experimental Workshops. The Organization also maintains Australian Scientific Liaison Offices in London and Washington.

The Divisions which have been established (in order of their formation) are as follows:—

Plant Industry, with head-quarters and main laboratories at Canberra, regional laboratories at Brisbane, Perth, Hobart, and Deniliquin, New South Wales, and field stations and experiment farms at Canberra, Australian Capital Territory, Lawes and Applethorpe, Queensland, Trangie, New South Wales, and Kojonup, Western Australia.

Entomology, with head-quarters and main laboratories at Canberra, a smaller laboratory in Sydney, and field stations at Trangie, New South Wales, Rockhampton, Queensland, and Perth.

Animal Health and Production, with head-quarters in Melbourne and main laboratories in Melbourne, Sydney, Prospect, New South Wales, and Brisbane, and field stations at Armidale and Badgery's Creek, New South Wales; Cunnamulla, Amberley, and Rockhampton, Queensland, and Werribee and Tooradin, Victoria.

Biochemistry and General Nutrition, with head-quarters at Adelaide and field stations at O'Halloran Hill, Robe, and Brecon, South Australia.

Soils, with head-quarters and laboratories at Adelaide, and branch laboratories at Perth, Canberra, Brisbane, and Hobart.

Forest Products, Melbourne.

Food Preservation and Transport, with head-quarters and main laboratories at Sydney, branch laboratories in Brisbane and Hobart, and minor laboratories at Gosford, New South Wales.

Fisheries, with head-quarters and main laboratories at Cronulla, New South Wales, laboratories in Perth and Melbourne, and field stations at Brisbane, Hobart, and Thursday Island.

Metrology, Physics, and Electrotechnology, comprising together the National Standards Laboratory, Sydney.

Radiophysics, Sydney.

Industrial Chemistry, with head-quarters and main laboratories in Melbourne and branch laboratories in Sydney, Adelaide, and Perth.

Tribophysics, Melbourne.

Building Research, Melbourne.

Mathematical Statistics, Adelaide.

The following are the Sections:—

Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria.

Radio Research Board, with head-quarters in Sydney and branch laboratory in Brisbane.

Plant Fibre, Melbourne.

Ore-dressing Investigations, Melbourne and Kalgoorlie, Western Australia.

Mineragraphic Investigations, Melbourne.

Oenological Research, Adelaide.

Dairy Research, Melbourne.

Meteorological Physics, Melbourne.

Tracer Elements Investigations, Melbourne.

Coal Research, Sydney.

Physical Metallurgy, Melbourne.

Wildlife Survey, with head-quarters in Canberra and field stations at Perth, Albury, New South Wales, and Aberdoss, near Marble Bar, Western Australia.

Mathematical Instruments, Sydney.

Wool Textile Research Laboratories, with head-quarters in Melbourne and additional units in Sydney and Geelong, Victoria.

Land Research and Regional Survey, with head-quarters in Canberra and field stations at Alice Springs, Northern Territory, Ayr, Queensland, Katherine, Northern Territory, and in the Kimberley region, Western Australia.

Agricultural Research Liaison Service, Melbourne.

Animal Genetics, Sydney.

In addition, Regional Centres (co-operative research units staffed with officers from the appropriate specialist Divisions to attack the problems of a particular district) have been established as follows:—

Tasmanian Regional Laboratory, Hobart.

Western Australian Regional Laboratory, Perth.

II. SOILS.

1. General.

Scientific appreciation of soils is basic to any proper land use in Australia. The efficient exploitation of existing land resources, improvements in farming methods, more intensive cultivation, techniques for pasture improvement, and measures for soil conservation all require a fundamental knowledge of the soil.

The Organization's work in this field is undertaken by the Division of Soils with head-quarters at the Waite Agricultural Research Institute of the University of Adelaide. However, some work on soils and their behaviour under irrigation is undertaken at the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria, and at the Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, New South Wales (*see* Chapter IV., Sections 2 and 3).

Division of Soils.—The Division does both applied and fundamental research into the classification, properties, and problems of Australian soils. The primary objectives are—

(i) The systematic mapping of the soils of Australia in broad categories as an evaluation of national soil resources and as a comparative survey relating pedologically the soil groups of this and other countries.

(ii) The classification and mapping in varying degrees of detail of the soils of specific areas in regions marked for future or more intensive settlement or in which problems of production have arisen; this is a service of immediate value to the farmer and to State advisory and administrative bodies.

(iii) Applied research into problems concerning soil fertility or other chemical or physical factors affecting productivity.

(iv) Fundamental research on the pedology, chemistry, physics, and microbiology of Australian soils. This is becoming an increasingly important activity on which depends the progress of applied research in the Division and also of investigations of other Divisions of the Organization and of outside agricultural authorities.

Pedology activities have swung more to broader-scale mapping with only a small amount of the detailed type as an aid in defining and interpreting the soil patterns mapped in broad groups. The first definite move to map regional units in categories suitable for a new soil map of Australia was made.

Considerable advances have been made in the study of the mineralogy of the soil, both the clay and the coarser fractions, as a guide to soil classification and to physical and chemical properties, as to understanding the genesis of soil profiles, and as a useful attack on the geochemistry of the soil, which may enter into fertility problems.

The approach to microbiological studies has broadened with the commencement of work on soil organic matter and humus, and on the nature and activities of organisms in the rhizosphere immediately adjacent to the roots.

The organization of the Division has remained essentially the same but the group concerned with soil mineralogy is in process of developing into a new section. There has been a change in senior officers in the Perth centre and a small new unit for field work has been set up at the Irrigation Research Station, Griffith, New South Wales. A new soils laboratory has been established at Canberra.

A Soil Survey Co-ordination Committee was set up in Victoria comprising representatives of the Department of Agriculture, Soil Conservation Authority, University, and the Commonwealth Scientific and Industrial Research Organization, to collate information on existing and current surveys and to decide on priority for and active parties in new surveys. This has the same function as similar committees in New South Wales and Queensland, and all were set up at the instigation of the Commonwealth Scientific and Industrial Research Organization. A further committee is being organized in Western Australia.

During the year a representative of the Division served as an Australian delegate at the Eighth Pacific Science Congress in Manila, Philippine Islands. Three officers have been overseas in America and Europe for part of the year on study leave and two are away on studentships in Sweden and England.

A notable move in publication is the Executive's agreement to issue a new *Soil Publication* series to include material previously included in the *Bulletin* series.

2. Soil Survey and Pedology.

(Division of Soils.)

(*a*) *Western Australia.*—A reconnaissance survey of the the Swan Coastal Plain made in previous years has outlined the soil associations of the area. Field work this year has been almost entirely concerned with filling in details of the pattern already described.

The major effort has been at Capel, where the soil survey of a proposed irrigation area was commenced last year. This year a further 60,000 acres were surveyed in detail, making a total of 130,000 acres of which approximately one-third is irrigable. A soil map and report giving a description of the soil types, their distribution, and irrigation potential is now in the course of preparation.

At Harvey, where some 8,000 acres had been covered in detail in other years, the area surveyed has been extended by 12,000 acres of which 3,000 acres are in detail.

The soil survey of the Swan valley is complete, and a *Soils and Land Use Report* on the work is now in press. A good deal of time has been spent on this and other compilations to complete the proper recording of field work already finalized.

Other minor projects during the year were a survey of the Manjimup Agricultural Research Station at the request of the Superintendent of Dairying of the Department of Agriculture, and one of the Seaforth Home property at the request of the Physical Education Branch of the Department of Education.

(*b*) *South Australia.*—Investigations in the past year in the low-fertility lands of the upper south-east have been concerned with two areas. In the Tintinara district a soil map and report on 300 square miles have been completed for publication. This area is mainly sandy, often in the form of high sand dunes liable to erosion. Saline ground-water is found generally several feet below the surface of the plains and is associated with the occurrence of saline soils. Determinations of soil salinity have been made at 2-monthly intervals through the past year on a number of sites to investigate the seasonal movement of soluble soils. In the Tatiara district, including Bordertown and Wolseley, the field work on 450 square miles has now been completed. This area adjoins earlier surveys in County Buckingham and approximately a third of it is also sandy and of low fertility. Another third represents the western extremity of the fertile Wimmera soils of Victoria. The balance is made up of variable deep and shallow stony soils, with many swamps. Most of the land is cleared and cereal growing is well established. Certain parts are particularly favoured for irrigation, using easily accessible groundwater of good quality. The high wheat yields obtained in this district testify to its fertility, yet even productive land here gives a response to zinc as a fertilizer for wheat and subterranean clover.

A reconnaissance survey was made of 25,000 acres in the Hundreds of Woolumbool and Lochaber in an endeavour to assess the suitability of this area for government acquisition and development to closer settlement. The soils are generally of low fertility; some are coarse-textured, deficient in organic and mineral matter, and liable to wind erosion if disturbed under summer conditions, but others have been developed elsewhere with suitable management. Salinity over a considerable portion is a material problem.

The soil survey of the Barossa district has been continued from last year. The *Soil and Land Use Report* on the first unit, the section surrounding Nuriootpa, is in press. Field work is almost completed at a moderate level of detail in both the second and the third units, the Seppeltsfield-Gomersal and the Tanunda zones respectively. Their combined area is about 30,000 acres. Field work has been started in the east Barossa unit over an area of about 55,000 acres extending from Angaston to Springton. Spot surveys of about 1,000 acres were made at both centres earlier this year to determine appropriate soil mapping units.

In continuation of the long-standing search for new areas suitable for irrigation development in South Australia, a soil survey was made in the latter half of 1953 of 17,000 acres in the Hundreds of Paringa and Gordon, County Alfred, between Loxton and Renmark on the Murray River. Of this total, 7,000 acres were surveyed at the detailed level and 10,000 acres in reconnaissance. This survey revealed a main unit of about 5,000 acres as suitable initially for irrigated horticulture and three smaller areas totalling 1,500-2,000 acres as suitable for future extensions. This area has many features similar to those of the nearby Loxton Irrigation Area and is commandable on a moderate pumping lift.

A soil survey of Martindale Estate, some 10,000 acres, at Mintaro has been completed in great detail. It will serve as a basis for experimental work by the Waite Agricultural Research Institute. The survey has revealed important details of the relationships of red-brown earths and brown soils of heavy texture to topographic features and their concomitant effects on the moisture regime of the soils thereon.

About 1,000 acres of undrained fen country in the lower south-east were examined for the Land Settlement Authority. This is a parallel case to the previously surveyed Eight Mile Creek Swamp, which has been successfully developed. Wellington Swamp, an area of 1,000 acres close to the point of entry of the Murray River into Lake Alexandrina, which has been flooded since 1917, was also examined by working from a boat. The object was to determine its suitability for reclamation and development along the lines of the Jervois Irrigation Area nearby. About 40 per cent. appears first quality swamp and 20 per cent. poor problem soils.

A preliminary inspection has been made on Yudnapinna Station and surounding areas of land north-west of Port Augusta as a suitable site for detailed pedological studies of arid soils.

Further work has been done both in detailed spot surveys and in broad-scale soil association mapping of areas in the Adelaide hills as part of a programme of surveying the Adelaide 1-mile military map.

Reports and recommendations have been made to State and Commonwealth housing authorities in Adelaide for the selection and planned use for building of estates purchased for intensive housing schemes. The volume of these requests appears to be decreasing.

(*c*) *Victoria.*—A reconnaissance soil survey was made of the Shire of Kowree, County Lowan, in western Victoria, as a joint operation with the Soil Conservation Authority. This Shire embraces 2,300 square miles and includes portion of the Little Desert, a sandy area, and the western end of the Great Dividing Range. A small proportion, the fringing hills and the valley of the Glenelg River, is subject to soil erosion, but the remainder is protected by either improved or natural pastures or by virgin forest or scrub. The improved pastures rely mainly on subterranean clover and Wimmera rye grass, which are grown on a variety of soils, the only fertilizer being superphosphate. There is some indication that these pastures do not remain at their initial high level of production and that the health of young sheep is not satisfactory. There is scope for further development by increasing the very small irrigated area—using underground or possibly surface water in swamps and lakes, by utilizing certain virgin land either for pasture or exotic forest plantations, and by increasing the small area devoted to stone fruits. The Shire contains the main intake for the Murray Artesian Basin and hydrological investigations are warranted for assessment of the annual intake to that basin.

(*d*) *Tasmania.*—The Tasmanian regional survey has been continued; one more unit, the Hobart military sheet of approximately 350 square miles, and about 60 square miles in the southern portion of the Buckland sheet have been completed toward the preparation of the new soil map of Tasmania.

The mapping of the soils of the whole of Flinders Island (area 550 square miles) has been completed, fifteen soil associations having been recognized. A total of approximately 4,000 acres of detailed survey was done in three of the major associations, which assisted in defining the pattern of types within each of them. Some of the units of the 1951 survey of the Foo Choo Flats have been modified to fit in with the subsequent survey of the whole island. In the area being developed at present for closer settlement, pasture responses to copper and lime, added to the usual heavy dressings of superphosphate, have been obtained.

The field work in the Launceston Basin, which covers an area of 850 square miles, is now complete. Accurate base maps for part of the area were available, but elsewhere they have been compiled photogrammetrically using the slotted template technique.

The first stage of the work in the Burnie-Table Cape area has been a broad-scale reconnaissance of the area, which has been successful in delineating the basaltic soils from those on other parent materials such as Palaeozoic quartzites, granites, and tillites, and Tertiary to Recent sands and clays. The total area is approximately 500 square miles.

A detailed survey covering a total of approximately 8,000 acres is being made of the basaltic soils in the Sorell-Bream Creek area. The basalt occupies old valley floors and has been much dissected. The soils represented range from krasnozems to black earths.

(*e*) *South-eastern Region.*—This region covers the irrigation zone and the greater part of New South Wales and eastern Victoria.

In the irrigation zone three areas have been surveyed in the past year and two large ones are in progress. East Murrakool (15,000 acres near the Murray River at Barham) has been mapped in moderate detail at the request of the Irrigation Commission as a potential new development. Apart from irrigability investigations the soils have opened up some interesting pedological features of importance to development and in understanding the history of the formations in geologic time. Two units each of 50,000 acres in the Murrumbidgee Irrigation Areas, one at Kooba and one at Whitton, have been surveyed as a moderately close study of soils of large-area farms and to form a basis for land-use and soil investigation following irrigation over a sequence of crops for a considerable period of time. This work has involved a study of the four depositional layers which have built up the landscape, providing a valuable aid in understanding the soil characteristics and distribution.

The survey of the large Billabidgee area south of the Murrumbidgee River, aggregating 700,000 acres, has begun as a co-operative enterprise with the Irrigation Commission and the Department of Agriculture. This project is basic for the evaluation of the tract of country generally considered suitable for irrigation development from the Snowy and Tumut River schemes, and should result in the selection of the suitable portions and soils for various purposes.

The Denimein Irrigation Area (130,000 acres), immediately north of Deniliquin, New South Wales, has been partly improved by irrigation in recent years but no survey had been made. Before development proceeds further the soils are being examined and mapped in associations.

The regional survey has been temporarily slowed down by pedological studies of soil formations in the Riverine Plain. From these investigations three riverine layers can be recognized, probably dating back to climatic fluctuations of the late Pleistocene.

A fourth layer has many of the characteristics of loess. The study of these layers and their distribution has received considerable attention and is proceeding. At present it seems that the characteristics and distribution of the four layers as surface exposures have a great influence on the soils and many problems are elucidated by reference to them.

Some preliminary reconnaissance of the soils in the Namoi valley has been made with a view to future use of irrigation water from the Keepit Dam. Further survey work needs to be done before irrigation development begins.

(*f*) *Queensland.*—Field studies of the soils of an east-west strip across the central Darling Downs have been continued. Following up the detailed spot surveys referred to in the previous Report, two field parties mapped the soils of the 500 square miles of country covered by the Toowoomba 1-mile military map at the soil series association level during the 1953 season. This work was done directly on aerial photographs of 40-chain/1-in. scale. A soil map has been prepared for publication at 1-mile/1-in. scale. An additional detailed spot survey of 1,400 acres of country near the western edge of the uplands south of Irongate was also made. In this area Mesozoic sedimentary rocks of the Walloon Series contribute to soil parent materials. These rocks are both calcareous and saline and some of the soils show evidence of solonization. In addition to black earths and small areas of solonetzic soils, there are some whose characteristics indicate close relationship to the red-brown earths.

As part of the Division's plan to produce a new soil map of Australia, a start has been made on broad-scale mapping of the soils of the Brisbane sheet of the Australian Geographic Map Series at a scale of 1 to 10^6. Most of this area lies on the coastal side of the Dividing Range. Topographically and geologically, it is one of the most complex areas in Queensland. For recording more detail along traverses and having suitable road information for traversing, 1-mile military map sheets are being used as base maps in the field where available. Elsewhere, 4-mile military sheets will be used. The mapping unit being used is the great soil group association.

A detailed survey has been made of the recently established Amberley Field Station of the Division of Animal Health and Production. This 450-acre property is made up of heavy soils derived from fine-textured alluvium along Warrill Creek. They are intermediate in character between black earths and grey soils of heavy texture, some showing hydromorphic and others weakly developed solodic features. Present indications are that their phosphorus status is very low.

(*g*) *North Australia.*—Work was commenced by the Land Research and Regional Survey Section, to which a soil surveyor from this Division is seconded, in the Gulf country of north Queensland. This project concerns the survey of an area of 90,000 square miles in the Flinders-Gilbert River region abutting the Gulf of Carpentaria. Co-ordination of the pedological data and soil classification is carried out by visits from head-quarters of the Division as far as possible.

(*h*) *Cartography.*—During the year 45 maps of varying sizes and numerous diagrams have been drawn. As the field data is almost all on aerial photographs, base plans are required for the transference and where necessary special plots are made.

3. SOIL CHEMISTRY.

(Division of Soils.)

(*a*) *Terra Rossa and Rendzina Soils.*—Throughout South Australia there are several areas of shallow, relatively undifferentiated red and black soils overlying highly calcareous material. These soils, which have been attributed to the great soil groups of "terra rossa" and "rendzina" respectively, occur under the same climatic régime and very frequently adjacent to one another on apparently similar calcareous parent materials. An examination of nineteen representative profiles, collected mainly from the vicinity of Adelaide and some also from the south-east of South Australia, has now been completed. An attempt has been made to establish the pedogenetic factors involved in the formation of these soils and their morphological relationships in terms of chemical and mineralogical properties.

It has been found that the chemical properties of these two groups of soils are very similar. However, their colour, which is their dominant morphological difference, can be related to the total organic matter and the free ferric oxide associated with the clay fraction. If nitrogen is used as a measure of soil organic matter, then the black soils are characterized by having a ratio of free ferric oxide to nitrogen of less than 10, while this ratio is greater than ten for the red soils. An increasing degree of redness does not always correspond with an increase in this ratio, but a mineralogical examination of the clay fraction has shown that any anomalies can be attributed to the presence of other iron-bearing minerals, such as chlorite, in the clay fraction.

(*b*) *Ion Exchange Relationships of Soils and Clay Minerals.*—An investigation into the ion exchange-pH relationships of various cation-dominant soils has now been completed. Typical soils containing clay minerals representative of the montmorillonite, illite, and kaolinite groups were saturated with one of the cations sodium, potassium, calcium, and magnesium and the equilibrium reactions with either the cation hydroxide or hydrochloric acid studied. After dialysis it was found that the relationship between the pH of the colloid and the negative logarithm of the amount of cation in the dialysate took the form of two straight lines, indicating that complex but definite reactions were occurring. Exchangeable cation-pH curves had a common shape in the acid portion of the pH range except for the kaolinitic soils which showed the highest buffer capacity per exchange position. The pH relationships with sodium as the metal cation were characteristic for the three clay mineral types and may be used to differentiate them.

Sodium was found to be easily hydrolyzed in soils containing illite minerals. This gives rise to high pH values at low sodium contents. Under these conditions the soil solution would have a high silica content.

Determinations of pH with the glass electrode in the soil suspension or in the dialysate indicated that equilibrium between the soil and solution was not readily attained under alkaline conditions. It is considered that this lack of equilibrium is associated with the hydroxyl ion. Increasing salt content did not assist in attaining equilibrium. It has been found possible to predict the change in pH for a salt addition provided that the metal ion concentrations in the dialysate are known. This difficulty in reaching equilibrium is of importance in the determination of the pH of alkaline soils.

The "suspension effect" in making electrode potential measurements in clay suspensions has been further investigated. Except for kaolinitic soils below pH 6, the monovalent cations sodium and potassium always gave positive potentials with respect to the calomel electrode in the dialysate taken as negative. The potentials developed by calcium- and magnesium-treated soils were always negative. If it is assumed that the suspension effect represents an average potential between the Gouy double layer and the outside solution, it can be shown theoretically that the suspension effect is a function of the reciprocal of the square root of the concentration of ions in the dialysate. The numerical values of the experimental results confirm this but the reason for the difference in sign between the monovalent and divalent cations is still obscure.

(*c*) *The Availability of Micro-nutrient Elements in the Soil.*—Further experimental work has been devoted to the elucidation of the chemical forms of manganese and other heavy metals in soils. The uptake of manganese by oats from different manganese compounds added to a highly deficient soil was determined. The soil used was a highly organic neutral soil from Rendelsham, South Australia. Past experience has shown that it requires very heavy applications of manganous sulphate to overcome the deficiency. The influence of different soil treatments on the availability of manganese in this soil was also examined.

The determination of the various chemical forms of manganese in soils has proved a most difficult problem in the past. The use of salts of ethylenediaminetetra-acetic acid has shown considerable promise and an improved method for the extraction of divalent manganese from soils has now been devised.

(*d*) *Rain-water Studies.*—In conjunction with the South Australian Department of Woods and Forests samples of rain-water have been collected weekly in certain forest areas and these have been examined for the common anions and cations. It has also been agreed to examine, for the Soil Conservation Authority of Victoria, rain-water representing 3-monthly periods of rainfall from 25 centres in Victoria, provided satisfactory arrangements can be made to prevent contamination during collection. This is still the biggest problem as analysis now presents no major difficultes.

(*e*) *Spectrochemical Investigations.*—A large series of soils, representing typical Western Australian lateritic profiles, has been examined spectrographically. Calcium, magnesium, copper, gallium, lead, manganese, and molybdenum were determined in the soils and also in the ferruginous concretions. This is part of the detailed study of these soils which is being carried out mainly in the Western Australian Regional Laboratory.

The spectrographic laboratory has continued to assist with difficult determinations. Mineral samples have been examined for thorium and uranium for the Bureau of Mineral Resources and other samples of pyrite and haematite for the South Australian Department of Mines. Assistance has also been provided in mineralogical and plant nutrition studies to the Waite Institute.

An investigation has been started to explore possible correlations in the concentrations of six elements (copper, gallium, magnesium, manganese, molybdenum, and vanadium) in a large series of samples of Urrbrae loam collected from a small area of 28 square feet. No correlation has been found between soil reaction and any of the above elements. Work is in progress to detect any possible correlation between pairs of elements. The clay and sand fractions have been separated from some of the samples and these are to be further examined.

Much attention has continued to be devoted to the development of the quantitative spectrographic technique. Precision in his laboratory has now reached a stage where no significant improvement is likely to result from trial and error modifications of procedure. An analysis of the total error of a single determination has therefore been commenced so as to be able to ascertain the part attributable to excitation of the sample and that attributable to measurement of line intensities. It has been found that the determination of a line intensity from a line density is subject to an error of about 2 per cent., and this has been further apportioned between the densitometer itself, the calibration curve for conversion of line density to line intensity, and variations in the photographic line image. However, it is apparent that this total error of 2 per cent. forms only a very small part of the total error of about 10 per cent. for a single determination. To bring about a significant overall reduction the errors associated with excitation of the sample must be reduced. The lack of stability of the discharge itself is only one of the factors causing these errors. Factors that have been investigated include the arc current, the basic composition of the sample, and the level of concentration of selected elements being determined.

In the application of spectrographic techniques to routine soil analysis there is a limit to the accuracy needed, and this is imposed by the sampling error of the soil sample itself. In an investigaiton of this error, in a series of 68 samples taken from a compact area of 28 square feet, it has been found that the sampling error for one sample is about 10 per cent. Combining this error with a spectrographic error of 6 per cent. (for a mean of triplicate determinations) it is seen that the total error is only 12 per cent., which is not much greater than the sampling error alone.

(*f*) *Improved Methods of Soil Analysis.*—A better understanding of soil pH equilibria has given a sounder theoretical background to the technique of pH determination and the electrode arrangements used in these laboratories. The method has also been examined to assess the errors involved in its routine application. Replicate determinations made consecutively upon the same day were found to have smaller errors than those made on different days. In a group of eight observers there were significant differences between the errors of individuals. The errors due to all the above causes have 5 per cent. fiducial limits of ± 0.09 pH unit for a single determination. The errors due to the lack of equilibrium between the soil and the aqueous phase occurred only above pH 5 but could give drifts as great as 1.0 pH unit under unfavorable conditions. It was found that in practice the errors due to the suspension effect were relatively small. The error of sampling, due to variations in the field over small distances of the order of ½ chain, showed 5 per cent. limits as high as 1.3 pH units.

For the first time a simple method for extracting the exchangeable cations in calcareous soils has been devised. Sodium, potassium, calcium, and magnesium can now be satisfactorily extracted and determined with no more difficulty than in carbonate-free soils. A survey of the solubilities of calcium carbonate and magnesite in a number of possible extracting solutions suggested the use of a normal solution of ammonium chloride in 60 per cent. ethanol adjusted to pH 8.5 with ammonia. In such a solution the alkaline earth carbonates have a solubility equal to or somewhat less than in air-free water. Comparative trials on a large number of soil types have shown that the new solution satisfactorily extracts the exchangeable cations and that no correction is needed for the solubility of the alkaline earth carbonates. The leachate contains sodium and potassium in a form which can be readily determined by flame photometry. Calcium and magnesium can also be simply determined by titration with ethylenediaminetetra-acetate after removal of the ethanol and ammonia. During this investigation it was noted that solutions of ammonium acetate always dissolved more calcium from its carbonate than did similar solutions of ammonium chloride or nitrate.

The interactions of sodium, potassium, calcium, and magnesium have been studied in relation to their determination in a flame spectrophotometer. Calcium has a marked effect on magnesium and further enhances the difficulties associated with the determination of this latter element. Fortunately the successful application of ethylenediaminetetra-acetate titrations for calcium and magnesium has rendered their flame determination unnecessary. Applications of simplified flame photometers have also been studied, particularly for the determination of sodium and potassium in rain-water and soil extracts. In some filter type instruments calcium interferes with the determination of sodium and suitable precautions must be taken to minimize this source of error.

A new colorimetric method for the determination of iron in plants, based on the photometric determination of ferric cupferronate in amyl acetate, has been developed.

(*g*) *General Soil Analysis.*—As in the past, examination of type samples collected by Divisional soil surveys and other soil surveyors has formed an important part of the activities of the laboratories. Now that the regional laboratories are functioning, the number of routine samples examined at head-quarters has decreased. This has made it possible to examine special features of selected samples in greater detail. Thus detailed particle size distribution studies have been made for groups of Riverine Plain soils and soils from Mintaro, South Australia; seasonal changes in salt and moisture content in soils from the upper south-east of South Australia and salt in soils from forest reserves near Adelaide have also been followed. Detailed chemical analyses of clays and other minerals found in soils have been carried out.

(*h*) *Western Australian Region.*—Work has proceeded on the chemical aspect of the nature of lateritic soil derivatives. The Physics Department of the University of Western Australia, who are using X-ray diffraction methods to identify the clay minerals in the 14 profiles selected, are awaiting chemical analyses to confirm certain of their findings and this work is going ahead. The spectrographic analyses of the minor components of both "fine earth" and gravel portions of 13 of the 14 profiles have been completed by head-quarters. In general, lower total values are reported in the gravels of these profiles for the elements copper, gallium, and molybdenum than previously, but no correlation has yet been attempted between these minor element values and known deficiencies on the related soil types.

The collection and analysis of rain-water samples has continued. Methods have been improved and are carried out completely within the region. Calcium and magnesium are titrated using versenate, sodium and potassium determined using the flame photometer, and choloride and sulphate estimated in the same sample by titrating with silver nitrate to give the usual electrometric chloride titration and continuing the titraion with barium acetate using the conductimetric sulphate method. Two pairs of samples were obtained from the top and bottom of a wireless mast, but the composition of corresponding samples was not very different although the volumes in both pairs were 50 per cent. higher at the bottom than at the top.

(*i*) *Queensland Region.*—Routine analyses have continued, to support the soil survey on the Darling Downs. As part of a plan to speed up routine soil analyses a rapid manometric method for carbonate determinations has been developed which more than doubles the output of results without significant loss of accuracy. Co-operative work with head-quarters on new titration methods for calcium and magnesium and on use of the flame photometer for sodium and potassium in soil extracts has also been undertaken.

Following the discovery of palygorskite at Flinders Peak, chemical work on samples of palygorskite and sepiolite was carried out with the help of the soil physics laboratory at Adelaide. This project is now complete.

Studies on the nitrogen status of black soils on the Darling Downs was continued. Similar trends to those reported last year in the soluble nitrogen fractions were found, and the studies were extended to the nitrogen status following ploughing up the native grassland. First results suggest that ploughing up releases considerable quantities of mineral nitrogen in the form of nitrate and that to some extent this nitrate is washed down to lower horizons in the profile. Percolation tests with ammonium sulphate solution reveal that nitrification potential decreases markedly with depth, and that lower depths are characterized by a marked accumulation of nitrate in the percolate before conversion to nitrate is finally complete. This behaviour is being further investigated.

Studies on the zinc status of these soils are also being continued. A large proportion of the total zinc is found in the clay fraction, where it appears to be difficult to remove by normal extraction solutions.

(*j*) *Tasmanian Region.*—Analyses have been carried out on certain aspects of the chemistry of alpine and dolerite soils in association with the field morphological study of the pedology of these groups. A large number of routine samples has been handled during the year, principally from the soil surveys described above.

4. SOIL PHYSICS.

(Division of Soils.)

(*a*) *Water Content and Volume Changes in Soils.*—Soil movements accompanying changes in water content of clay soils can cause serious difficulties in foundations of buildings and roads. Measurements already made of seasonal changes in clay soils have improved the basis for design of house foundations on such soils. These measurements are being continued. Additional moisture measuring devices have been installed under four new houses in Adelaide suburbs with the object of following changes in water content from the time the houses were first roofed.

Measurements of vertical movement due to swelling of clay are also being continued and cells have been installed to measure the swelling pressures exerted in the field. This is a long-term project to follow changes over a series of seasons of varying character. The present objective is to determine the effect of lateral pressure on the piers of foundations in relation to lifting of the piers in swelling soils.

(*b*) *Measurement of Soil Water Status in the Field.*—The neutron method of measuring soil water content is being adapted for use in the field. It promises to be particularly useful in variable soils because it measures a volume of about 1 cubic foot of soil, thus tending to average out the scatter obtained in individual soil samples of smaller size. Attention is also being given to the development of techniques to measure soil water status in arid conditions. An attempt is being made to assess quantitatively the accuracy to be expected from the gypsum block, which is used extensively as a field unit.

(*c*) *Examination of Soils for Building Purposes.*—The soils at the site of the Northfield Mental Hospital near Adelaide, where a large building programme is projected, continue to receive attention. One problem, not only of these soils but of other similar ones in the northern parts of Adelaide, has been the accumulation of free water in the form of a perched water-table under buildings. It has been established that this condition is aggravated if not entirely caused by excessive watering of gardens in the vicinity. The soils possess a relatively impermeable horizon of stiff clay at some depth in the profile, which permits the horizontal flow of large quantities of water when a water-table builds up on it. Measures to remedy this trouble have been suggested. Advice on the merit of sites for group housing has also been given to the Commonwealth War Service Homes Division.

The soils of the suburban areas of Adelaide have been described in a bulletin issued jointly with the Mines Department. An account is given of the behaviour of each of the soil types in relation to house foundations.

(*d*) *Soil Structure.*—Further work is being carried out on the effect of initial water content on the water stability of soil aggregates. In general, the higher the water content of the soil before it is placed in water, the greater will be the stability. The relative effects on cultivated and virgin soils are being examined. At the same time an attempt is being made to evaluate the factors responsible for differences in stability.

The effect of cultivation upon structure is being examined in the Darling Downs, Queensland. In the Murrumbidgee Irrigation Areas, New South Wales, the effect of rice growing on structure is under investigation, the condition of soils of the same type being compared after 8, 4, 2, and no crops of rice.

In connexion with the chemical and mineralogical study of soils of the terra rossa and rendzina groups outlined in Section 3 (*a*) of this Chapter, a study is being made of the structure of these soils in relation to aeration and development of the soil profile.

A method has been developed for measuring the apparent density of aggregates down to 2 millimetres in diameter within an accuracy of 2 per cent. The aggregates are evacuated to remove air in them, wetted with kerosene, and drained at a small tension; their volume is determined by displacement in kerosene.

(*e*) *Surface Area of Soils.*—A study has been made of the application of the adsorption isotherm of Brunauer, Emmett, and Teller to adsorption of water vapour by soil. Some preliminary results show that surface area of clays determined by this means may be considerably higher than when determined from nitrogen adsorption. In view of the significance of surface area in the physical properties and chemical reactivity of clay soils, these results may be important, and may extend the information available from particle size analysis, which does not normally extend into the range of the finest particles. Alternative methods of measuring the surface areas of soils are being tried using negative adsorption and ethylene glycol. Preliminary work with negative adsorption and chloride in the presence of calcium chloride has given an area of 56 m.^{2}/g. compared with 43 m.^{2}/g. by nitrogen adsorption.

(*f*) *Soil Physical Properties and Electrolyte Concentration.*—The effect of electrolyte concentration on the permeability and swelling of soils is being investigated. It is intended that the results of the permeability work will be used in maintaining the permeability of certain soils which have appreciable quantities of sodium on the exchange complex. For each degree of sodium saturation there is a particular level of electrolyte required in the irrigation water to maintain stable aggregation of the soil. If the level of electrolyte is too low, decreases in permeability are obtained owing to dispersion. By adding a calcium salt such as gypsum to the irrigation water, the permeability of the soil is maintained, while the sodium associated with the clay is replaced by calcium. When this process is complete it will not be necessary to add calcium salts to the irrigation water. The present work has added more precision to a reclamation process which has long been used in irrigation practice.

The work on the swelling of clay blocks has been extended to a study of the effect of electrolyte concentration and exchangeable cation on the degree of swelling. This is related to the above-mentioned research on swelling (Section 4 (*a*) of this Chapter). So far it has been shown that the level of electrolyte results in only small differences in the degree of swelling of the calcium-saturated clay within the range likely to be encountered in the field. The work is being continued for a sodium-saturated clay.

In connexion with work proceeding on liquid and vapour flow through soils it is necessary to know if the moving concentration in the liquid is well evaluated by the ratio of total chloride to water content. It has been shown that errors involved in this assumption are small owing to the compensating effects of negative and positive adsorptions at the particular pH value of the soils.

(*g*) *Erosion and the Formation of Surface Seals.*—Laboratory and field measurements are continuing on the study of soil splash, and the formation and properties of surface seals under the impact of raindrops. Test plots for field work are all on the one soil type but have had different agricultural treatments. Treatment differences show up in both the amount of soil splashed and its particle size distribution.

Damage to soil surfaces comparable with that observed in the field is carried out in the laboratory with a rain simulator, the drop energy being varied by its distance of fall. With high energies more splash occurs on the well-aggregated stable soil owing to the movement of relatively large aggregates, but on the unstable soil the splash consists of highly dispersed particles and therefore damage is greater. On all soils the amount of splash from the surface reaches a constant value as the total energy dissipated at the soil surface is increased. Amount of splash depends also on the rate of wetting. As might be expected, seal formation occurs much more rapidly and to a greater extent on the unstable soils. The effect of seals on air-water-soil relationships is being investigated with laboratory- and field-formed seals, and the make-up and properties of seals are also under study.

(*h*) *Permeability.*—Results obtained from the movement of water and chlorides and columns of soil from which water is allowed to evaporate at one end show that in isothermal conditions water flow occurs as liquid in soils wetter than wilting percentage, with negligible vapour flow. The evaporating soil columns have given results relating the rate of flow of water to the tension gradient within the columns, from which some values of unsaturated permeability have been calculated for water contents down to the wilting percentage.

(*i*) *Shrinkage of Soil Aggregates.*—A study of the shrinkage associated with the drying of natural aggregates has been carried out at the Brisbane regional centre. The modifying effects of texture and structural development were assessed. The effect of shrinkage upon crack formation and subsequent water entry in field soils was studied. In addition to the normal and residual stages recognized in shrinkage of puddled blocks, an additional stage termed "structural shrinkage" is found in natural aggregates. This difference from the puddled condition provides an opportunity for assessing the degree of structural development of a soil.

(*j*) *Water Content Changes in Natural Soils.*—A joint project with an officer of the Ecology Section, Division of Plant Industry, has been commenced at the Brisbane regional centre: to define the micro-habitat conditions for various rain-forest communities. This includes following the seasonal variation in water content of the soils at various depths. Gypsum blocks and associated equipment have been installed and are being read at approximately monthly intervals. Measurements of rainfall, humidity, and temperature are also being made and it is hoped that the contribution to water loss from these soils via evaporation, transpiration, and run-off will be determined.

(*k*) *General.*—Routine characterization of soil survey samples for degree of aggregation, porosity, and range of available water has been carried out in the Plant and Soils Laboratory, Brisbane, and facilities for similar work are being set up at Canberra. The index for assessing the physical status of soils referred to in the last Report has been further tested upon routine soil samples. The aim of the index is correlation with agricultural potential. A preliminary statement on the index has been prepared.

(*l*) *Terra Rossa and Rendzina Soils.*—Work on the terra rossa and rendzina soils from South Australia has been completed as a contribution towards the research on these groups described in Section 3 (*a*) of this Chapter. Mineralogical examination of the formations shows that the underlying shales are the parent materials of the soils, the carbonate in the lower horizons influencing the type of profile formed. The degree of redness of the soil is related to the amount of free iron oxide present, and this in turn is governed by the amount and type of iron-bearing mineral in the underlying shale. The amount of free iron oxide present in the soils appears to determine also the size distribution of the pores and related field behaviour of the soils. The soils are best understood when regarded as varying continuously from black to red, rather than as two distinct groups.

(*m*) *The Occurrence of Palygorskite in Queensland.*—The clay mineral palygorskite (or attapulgite) was first identified as a contaminant in dolomite from a dolomite quarry near Ipswich, Queensland. Subsequent investigation showed that the mineral occurred extensively both as a pure clay and mixed with dolomite and other minerals. The geology and mineralogy of the deposits indicates that the palygorskite has been derived from sepiolite which was formed in freshwater lakes with the dolomite in Tertiary times. This is the first recognition of the mineral in Australia, and it is of interest as the clay has many commercial and industrial applications. The owners of the dolomite quarry are interested in exploiting the clay, and the Division of Industrial Chemistry is determining its suitability as an oil clarifier &c. Samples of fuller's earth from various localities have been examined but palygorskite was not identified in them.

(*n*) *Swelling and Non-swelling Soils of Melbourne.*—An investigation of the soil colloids of some Melbourne soils showed that montmorillonite was the dominant clay mineral of those soils with poorest foundation characteristics. The clays in the soils are dependent on the parent rocks, basalt giving montmorillonite, and shales and sandstones giving illite and kaolin, which do not exhibit the undesirable swelling characteristics.

(*o*) *X-ray Diffraction Techniques.*—In studying clay minerals it is essential that diffraction cameras can record high spacings. To aid in the rational design of these cameras an investigation has been made into the variation of diffracted intensity with respect to X-ray wave-length, exciting voltage, and angle of viewing the X-ray target. The results show that cameras to record high spacing can be designed without loss of efficiency if the target is viewed at 2–3° instead of the conventional 6°.

The testing and assembling of Geiger counter equipment has been completed in anticipation of using counter techniques in diffraction. It is hoped that using these techniques analyses can be made quickly and at least semi-quantitatively.

(*p*) *Service Work.*—In connexion with the phosphate fixation studies being made in soil chemistry and microbiology many phosphate minerals and some other minerals were analysed to establish their purity and crystal structure. A similar examination was made of some manganese minerals being used to investigate the availability of manganese in soils (*see* Section 3 (*c*) of this Chapter). Soils from New Guinea, Queensland, and Tasmania have been analysed in connexion with surveys being carried out in these areas. Crystallographic and mineralogical studies have been carried out for the South Australian Mines Department, the Defence Research Laboratories, and the Chemical Engineering Department of the University of Adelaide.

5. Soil Microbiology.

(Division of Soils.)

(*a*) *Major Elements and Soil Microorganisms.*—Using macro-respirometers developed in the Division's laboratory, studies were made of the influence of the availability of nitrogenous and phosphatic materials upon the respiration of the soil microflora. A selection of inorganic and organic nitrogenous manures were tested and classified into three groups depending on their levels of availability: (i) nitrates, ammonium salts, urea, asparagine, yeast extract, casein, and peptone—good sources of available nitrogen; (ii) fungal mycelium, yeast cells, and red clover—fairly good suppliers of nitrogen; (iii) cereal straws, sawdust, and α-humus—poor sources of nitrogen. This order, obtained with soil microorganisms, closely parallels that found for plants.

Numerous phosphatic fertilizers and organic phosphates were also tested and divided into three classes: (i) alkali phosphates, superphosphate, serpentine-phosphate, silicophosphate, glycerophosphate, and nucleic acid—readily available sources of phosphate; (ii) basic slag, ferric phosphate, dicalcium phosphate, defluorinated rock phosphate, aluminium phosphate, and lecithin—fair suppliers of phosphate; (iii) rock phosphate and phytates—poor sources of phosphate. Again the soil microorganisms behaved similarly to plants.

A number of phosphatic minerals containing calcium, iron, or aluminium were checked by X-ray analysis, then bioassayed for available phosphate. None were good sources of phosphate; the minerals brushite, newberyite, and vivianite provided fair amounts of phosphate; but wavellite, turquoise, lazulite, variscite, strengite, dufrenite, fluoro-chloro-, and hydroxyapatites, and monazite were poorly available. In general, phosphates with the metal tetrahedrally co-ordinated were more available than those with hexagonal co-ordination.

(*b*) *Rhizobium-Clover Studies.*—Studies have been made upon the virulence and incursion of strains of *Rhizobium trifolii.* Preliminary tests have been made of the patterns of virulence exhibited by 40 strains of rhizobia isolated from a number of species of *Trifolium.* Upon inoculation back on to a range of clover plants grown under aseptic conditions in test-tubes, strains which tended to be highly virulent, i.e. produce sufficient infections to give rise to abundant nodular tissue, generally exhibited this property over each of the four test species used, viz.: *T. subterraneum, T. cernuum, T. alexandrinum,* and *T. fragiferum,* although a few exceptions were noted. The tests are being extended to further clover species. Comparative field and pot experiments with subterranean clover have shown that strains of *Rh. trifolii* which are effective under glass-house conditions are not always effective under field conditions. Conversely, strains which give good responses in the field are not always highly effective under glass-house conditions. This illustrates the importance of assessing the incursive properties of the bacteria before using them for seed inoculation purposes.

(*c*) *Fractionization of Soil Humus.*—This work is concentrated on trying to isolate proteins and polysaccharides from soil humus by electrophoresis. Proteins were not detectable on paper electrophoretograms of sodium humate by the bromophenol blue-mercuric chloride method. The mechanism of this test for proteins was studied to improve its sensitivity. Using a number of purified proteins and dyes it was found that the affinity of certain anionic dyes depended on cationic groups on the proteins, so that basic proteins stained more intensely than acidic proteins. Dyeing was enhanced by fairly acidic conditions which increased the positive charges and reduced the negative charges on the proteins, but diminished by alkaline conditions which had the opposite effect on ionizing groups on the proteins. The presence of other anions did not competitively inhibit the adsorption of dye. Insoluble esters of numerous amino acids were prepared and tested for their staining reactions. Esters of the basic amino acids histidine, arginine, lysine, and homocystine dyed more intensely than those of other amino acids. Despite efforts to destroy imidazole, guanidine and ε-amino groups on proteins by specific reagents, dyeing remained fairly good.

Aqueous solutions of dyes wetted the protein spots on paper poorly, resulting in patchy colours. This was overcome by adding detergents but better still by using alcoholic solutions of the dyes. Bromophenol blue-acetic acid-ethanol was the best of 40 dyes tested, since the proteins were dark blue against a white paper background. Others which were fairly good included most other sulphonphthalein pH indicators, Solway purple, Solway green, and Carbolan yellow. Light green, methyl green, and naphthalene black 12B were poor since they left too much background colour.

Polysaccharides were not detectable on electrophoretograms of sodium humate run in borate buffers over glass cloth instead of paper, and the reasons for this are being investigated.

(*d*) *Oxidation of Hydrocarbons by Soil Microorganisms.*—Paraffin-oxidizing organisms are common in Adelaide soils, especially those under grass. Eucalypts are known to be rich in hydrocarbons, but grasses are not, therefore an investigation has been started to find the types of hydrocarbons utilized by bacteria isolated from soil. All isolates were tested for their ability to oxidize straight-chain aliphatic hydrocarbons and one unidentified, Gram-positive bacterium was selected for studies on intermediary metabolism.

The Warburg respirometer was used to test the ability of this bacterium to oxidize the following straight-chain, aliphatic substances: saturated hydrocarbons (C_6 to C_{18}), unsaturated hydrocarbons, fatty acids, aldehydes, alcohols, and amines. The ability to oxidize the following ring compounds has also been measured: saturated and unsaturated hydrocarbons, aromatic acids (substituted and unsubstituted). Tests have also been made of the simultaneous oxidation of mixtures of certain hydrocarbons. The effect of many inhibitors and of phosphate deficiency upon oxidation of hydrocarbons and derivatives has been noted.

III. PLANTS.

1. General.

Plants, whether in the form of crops or pastures, are the basis of every agricultural industry, and viewed in perspective grass is Australia's most important primary product. The Organization has placed considerable emphasis on investigations of plant problems at the Division of Plant Industry, which has its head-quarters in Canberra and is the Organization's oldest Division. The work of the Division, which has experimental farms and field stations throughout the Commonwealth, is described in this Chapter.

Allied work on mineral nutrition of plants carried out by the Division of Biochemistry and General Nutrition is described in Section 11 of this Chapter.

Work on special local problems of irrigation districts is undertaken at the Commonwealth Research Station (Murray Irrigation Areas) at Merbein, Victoria, and the Irrigation Research Station (Murrumbidgee Irrigation Areas) at Griffith, New South Wales (see Chapter IV.).

The Division of Entomology is carrying out work on weed control, insect pests of pastures and crops, and insect vectors of virus diseases (*see* Chapter IX.).

The Land Research and Regional Survey Section is carrying out broad-scale ecological surveys in the underdeveloped arid and semi-arid regions of the continent, to assess their land-use potential and investigate problems of agricultural and pastoral development. The work on these regional surveys is reported in Chapter XI., Section 2, and the Section's investigations on crops, fertilizers, plant diseases, tillage, and native and introduced pastures under dry-land cultivation at the Katherine Research Station, and under irrigation at the Kimberly Research Station, are reported in Chapter XI., Section 3 *et seq.*

Research on biophysical aspects of plant growth is being undertaken at the Physics Department of the University of Tasmania and is reported in Section 22 of this Chapter.

Division of Plant Industry.—The research work of the Division is concentrated on problems which are fundamental to agricultural production in Australia. In this it is complementary to the activities of the State Departments of Agriculture, whose particular function it is to serve the more immediate needs of the agricultural industries.

Because of the great importance of pastures in the Australian economy and also because of the difficulties of establishment, utilization, and maintenance of improved pastures, many of the Division's activities directly or indirectly serve the pastoral industries of the Commonwealth. However, research work on other crops which require a particular effort in their introduction, establishment, or management, is included in the programme.

Agronomic and agrostological research is thus the first line of the Division's activities. Complementary to this work studies are in progress of a more fundamental nature designed to contribute to general knowledge of plant life and plant production.

Research in genetics has been re-established in Canberra during the past year. Studies have been commenced on the processes of genetic adaptation by which introduced plants are fitted into new environments, with reference initially to important pasture plants in southern Australia. The microbiology team has also been both enlarged and reorganized.

Considerable expansion has taken place in the work in agrostology and agronomy in Queensland where the Division now has, under its Associate Chief, Dr. J. Griffiths Davies, a team greatly strengthened by new appointments and transfers of staff from Canberra. Research which is to open up the coastal lowlands of south-eastern Queensland for intensive pasture development has made good progress. Nutrient deficiencies and their effect on the establishment of promising legumes and their *Rhizobium* symbionts have been further elucidated.

A significant discovery at Canberra indicates that clovers may compete with grasses for the nitrogen which they themselves assimilate and that in fact grass development may suffer from competition for nitrogen by the associated clover. To keep legumes at full efficiency of nitrogen assimilation, it seems necessary to utilize the nitrogen they incorporate in the soil, either in the shape of hay removed from the area or by cropping.

The first building extensions to the head-quarters laboratories at Canberra are completed and several of the Division's activities are now adequately accommodated.

The Chief of the Division, Dr. O. H. Frankel, paid a brief visit to the United Kingdom, Europe, and the United States in an endeavour to advance the Division's search for both senior and junior research personnel in a number of fields. Several new appointments have resulted. Dr. Frankel represented the Organization at the Ninth International Congress of Genetics at Bellagio, Italy.

Mr. C. M. Donald, Assistant Chief of the Division and leader of the research group in agronomy and agrostology in southern Australia, was appointed Professor of Agriculture in the University of Adelaide. He has been succeeded by Mr. R. M. Moore.

The Division continued its co-operation with many State and Commonwealth Departments and universities and with overseas organizations.

In a project jointly sponsored by the Food and Agriculture Organization and the Commonwealth Scientific and Industrial Research Organization, an officer of the Division was charged with collecting pasture species of interest to both Australia and the Mediterranean countries in which the collections are being made.

The Division continued to provide both long- and short-term specialized training to holders of F.A.O. Fellowships and of Fellowships under the Commonwealth Technical Assistance Co-operation Scheme. Senior agricultural officers from Chile, Cyprus, India, and Israel spent from two to nine months with the Division.

2. Plant Introduction.

(Division of Plant Industry.)

(*a*) *Plant Introduction and Exchange.*—The introduction of new varieties of plants from abroad was carried out on a restricted scale. This was largely because facilities were fully taxed. Introductions from previous plant exploration in the Mediterranean region and in Africa were still awaiting trial in quarantine nurseries at the beginning of the current year. However, all have now been grown, while more intensive studies were made of selected groups. There was an increase in demand for Australian seed samples from overseas countries, and also for the distribution of seeds of promising introductions within Australia.

(*b*) *Overseas Plant Exploration.*—The experience gained from previous plant exploration in the Mediterranean region made it clear that a much more detailed collecting expedition was required in those areas which a rapid survey three years ago showed to be of great value to Australia. Further it was evident that the Division was able to give substantial assistance to Mediterranean countries in developing their own indigenous pasture plants. This led to a project jointly sponsored by F.A.O. and the Organization for a plant collecting expedition to north Africa and the Mediterranean region.

The first stage of the work involved survey visits to Libya, Algeria, and Morocco. During those visits contact was made with local agricultural and botanical research workers. Botanical collections are being made and root nodules of leguminous species have been collected for rhizobial isolation. Collections will be made of potentially useful pasture plants, including species of *Phalaris, Lolium, Medicago, Trifolium,* and *Dactylis.* These collections will supplement previous collections from the Mediterranean region.

A study of different techniques in the collection, packing, and transport of legume nodules is proceeding to determine the most suitable method of transporting such material over long distances, and of ensuring its survival for a long period of time. The results of this study will be utilized to ensure that the most effective nodule strains are obtained whenever a leguminous plant is introduced for trial.

(*c*) *Agronomic Trials.*—Agronomic trials of new and old introductions have continued at all centres. At Brisbane and Perth new introductions were under trial for the first time. Several of these show promise but further work is required.

Introductions which have previously shown promise underwent further tests at both the primary introduction stations and various regional centres. At Kojonup, Western Australia, a special search is being made for perennial pasture plants able to survive the long dry summer, and also for annual grasses which might usefully replace Wimmera ryegrass in some of the pastures. Two introduced strains of cocksfoot proved particularly valuable in the south-western portion of Western Australia. Seed supplies were built up and the varieties have been released for general distribution by the State Department of Agriculture.

The value of *Sorghum almum* as a pasture plant in the drier areas of northern New South Wales was confirmed during the year. In large-scale trials in the Moree district this grass carried stock at the rate of more than one animal per acre throughout the year. However, in other areas there were some stock losses from cyanide poisoning arising from the particularly adverse climatic conditions which were experienced. Further when grown in the areas of higher rainfall some of the plants of *Sorghum almum* developed long rhizomes and could therefore be a potential weed of agricultural land. Efforts are being made to obtain strains of the grass free from these defects to permit of its utilization over a wider area.

(*d*) *Plant Growth Studies.*—The growth and development studies of selected groups of pasture plant introductions from the Mediterranean region reported last year were extended. The phenological development of these introductions, both at Canberra and in Perth, showed close relationship to their place of origin, but several exceptions have occurred which suggest that explanations must be sought in a study of temperature and light. By contrast there was an almost complete absence of any apparent correlation of morphological characters with place of origin.

To obtain more quantitative information about the growth cycle in some of the introduced strains of *Phalaris,* large single-plant populations were established at Canberra. In Perth the main emphasis has been on defoliation studies on an individual plant basis, to supplement the preliminary agronomic assessment made during the first year's trial.

Owing to unfavorable climatic conditions experienced on the Northern Tablelands of New South Wales, it was not possible to establish similar work in the Armidale district on the same scale. However, a preliminary assessment of some of the strains of *Phalaris* indicates that they have considerable superiority over commercial strains of this grass at Armidale.

(*e*) *Plant Geography.*—The large-scale vegetation map of Australia completed last year was checked and amended before going to press. This map incorporates new information provided by recent surveys, and will be used as the basis for a more generalized map to be published in a revised edition of "The Australian Environment". Apart from its direct value as one section of an atlas of Australian resources this work will serve as one basis for the critical comparison of Australian regions with others overseas.

A study aimed at understanding the effects of the major climatic elements on plant distribution and development is in progress in Queensland. As a result of a very detailed investigation of all available data regarding plant growth under varying climatic conditions, an integrated theory has been formulated of the effect of temperature, light, and day length on plant growth. This theory is being further developed and is being used as the basis of a revised climatic map of Australia which will be of fundamental significance in plant growth studies.

3. GENETICS.

(Division of Plant Industry.)

(*a*) Trifolium subterraneum.—(i) *Breeding.*—Subterranean clover is difficult to hybridize by the usual mechanical methods. Optimum germination of subterranean clover pollen on artificial media occurs at humidities above 95 per cent. and at temperatures between 20 and 25° C. Thus crosses are more successful in early spring during cool, showery weather. Emasculation is done by removing the folded corollas with attached stamens and anthers in the early bud stage. The exposed stigmas are then pollinated on several successive days. If the weather is warm and dry, the plants are kept in cool and moist conditions.

Using the improved hybridization technique, progenies from crosses between selected varieties were developed. The best agronomic phenotypes occurred in the crosses Tallarook x Dwalganup, Tallarook x Northam First Early, Mount Barker x Dwalganup, and Mount Barker x Northam First Early. A number of the F_2 segregates combined vigour and density with early flowering. These hybrids may prove to be better than the early varieties now in use.

A mosaic disease found in the Canberra area and elsewhere is caused by Phaseolus virus 2. The majority of the varieties gave a mottle reaction when inoculated with this virus, but Northam First Early, Dwalganup, and Pink Flowered reacted with lethal necrosis. These lethal-reactors had a high field resistance to the virus. Crosses between mottle-reacting varieties gave F_2 progenies with mottle reactions, while crosses between a mottle-reactor and a lethal-reactor had a preponderance of lethal-reactors in the F_2. The most promising crosses was Tallarook x Northam First Early, since a quarter of the F_2 progeny were highly resistant to hand inoculation with Phaseolus 2.

(ii) *Studies in Natural Selection.*—Preparations are in progress for studies of plant adaptation and response to natural and artificial selection. A study will be made of the rates and directions of change of different characters in hybrid populations derived from many diverse crosses which are to be exposed to different environmental treatments. Similar mixtures of plants will be exposed to a range of different types of natural environments—many of them marginal for the species—to encourage the natural selection of adaptive types. These studies must lead to a better understanding of the processes of adaptation, which in turn will provide a fuller understanding of methods of successful introduction in other species and genera; there are also good prospects that they will produce strains of agronomic value in marginal zones which will allow of the expansion of the area in which this valuable pasture species can be grown.

Preliminary experiments are in progress to assess the problems of measurement and sampling, and to devise methods to induce flowering and seed setting twice a year by vernalization and photoperiodic treatment, which would accelerate the early stages in breeding studies. Hybridization and seed multiplication are being continued on a large scale to provide seed for the experiments on plant adaptation.

(iii) *Autotetraploidy.*—The induced tetraploids of the Dwalganup, Cranmore, Mount Barker, Wangaratta, and Tallarook varieties had coarser and larger leaves than the corresponding diploids. Only in the Dwalganup variety was dry matter production increased by tetraploidy, the increase being 60 and 65.5 per cent. at flowering and maturity respectively. In all varieties, reduced seed setting followed autotetraploidy, but in Dwalganup, owing to the increased number of flowers, the yield of seed per plant was not affected.

(*b*) *Phalaris.*—The allotetraploids, from *P. caerulescens* x *P. minor* ($2n = 42$) are annuals. The allohexaploids from *P. tuberosa* x *P. minor* ($2n = 56$) are perennials and appear to be promising pasture plants owing to their early vigorous growth. Bulk selections of the desirable segregates from the latter are being allowed to intercross naturally to build up seed supplies.

(*c*) *Lucerne.*—A collection of Australian lucerne ecotypes has been made and will be extended. A study is being made of the character differences between these ecotypes. A hybridization programme is planned with the aim of producing a type of lucerne which will be suitable for grazing in the drier pasture areas.

(*d*) *White Clover.*—A world survey of white clover has shown that the gene frequencies for the cyanogenetic glucoside lotaustralin, and the enzyme linamarase which liberates hydrocyanic acid from the glusocide, are related to winter temperatures. A similar survey is being made on altitudinal populations of white clover in Australia.

(*e*) *Interspecific Hybridization.*—A prgroamme of interspecific hybridization in the Australian grasses is planned. This work is hampered by a general absence of basic cytological information. To bring together all the known information a list of chromosome numbers of Australian plants is being prepared and chromosome numbers are being determined in the following genera: *Stipa, Danthonia, Triodia, Hordeum, Cenchrus,* and *Chloris.*

Hybridization is being attempted between *Hordeum bulbosum* and *H. vulgare* in an effort to produce a type of *H. bulbosum* without its present undesirable awn characters.

(*f*) *Cytological Polymorphism.*—It is now fairly clear that cytological polymorphism plays an adaptive role in the evolution of genetic systems although the exact mechanisms of the adaptive processes are not yet clear. A grasshopper (*Crypthobothrus chrysophorus*) which is widespread in eastern Australia exhibits in its natural populations several alternative types of cytological polymorphism. Populations from the Canberra plains (elevation approximately 2,000 feet) have supernumerary chromosomes in 20-30 per cent. of the individuals. Populations from the adjacent Brindabella range (4,000-4,600 feet) show an entirely different type of cytological polymorphism. In these "mountain" populations supernumerary chromosomes are virtually absent but unequal chromosome pairs (owing to the presence of extra heterochromatin in one homologue) are extremely common. In addition a pericentric inversion which is common in some "plains" populations has not been found in the mountain populations. The species thus seems to consist of two races with different mechanisms of adaptive polymorphism.

Supernumerary chromosomes have been found in another grasshopper (*Atractomorpha crenaticeps australis*). Preliminary results are of considerable interest. Populations in the Canberra area have a mean of approximately 1.5 supernumeraries per individual, as many as four being found in some insects. This is a considerably higher frequency than in any other species of grasshopper studied until now. Since some other populations of *A. c. australis* and a colony of *A. c. crenaticeps* near Sydney have few or no supernumeraries, it seems that conditions in the Canberra area favoured a striking build-up of these chromosomes in the population. These studies will be continued with particular reference to altitude and distance from the coast.

Structural heterozygosity for pericentric inversions has been found in several species of the grasshopper genus *Moraba.* Work on this genus will be continued.

(*g*) *Chiasma Localization.*—The restriction of genetic crossing-over to certain regions of the chromosomes leads to the phenomenon of chiasma localization. This is probably more widespread in plants and animals than has been generally supposed and its role in the genetic systems of those species where it is strongly developed is far from being understood.

Preliminary studies have been made of chiasma localization in several species of the Australian grasshopper genus *Austroicetes.* Distribution of chiasma is significantly different in *A. vulgaris, A. cruciata* and *A. pusilla,* with an unusual type of localization in *A. vulgaris.*

4. GENERAL BOTANY.

(Division of Plant Industry.)

(*a*) *Structural Botany.*—Further work has substantiated the morphological sequences of the development of spikelets in basal sterile speltoid wheats reported last year. Studies of the histogenesis of spike, spikelet, and flowers in both normal *Triticum vulgare* varieties and the speltoids have now been completed. Flower primordia originate in the division of a plate of the cells in the subhypodermal layer. The lemma, palea, carpel, and lodicules develop from division of cells of the dermatogen and hypodermis in the same way as foliage leaves. The stamens originate in subhypodermal tissue. Complete sterility in the speltoid types may arise either as failure to initiate flower primordia or as failure of primordia before floral parts have differentiated. The production of incomplete and therefore sterile flowers originates in the failure of the flower primordium at a very early stage to differentiate floral parts.

Sterility in two types, St$_1$ and St$_2$, increases from the tip of the spike to the base, but in a third type of different origin, St$_{1A}$, sterility is greatest at the centre of the spike and fertility increases progressively both towards the apex and base of the spike. Examination of St$_{1A}$ in the early stages of spike development will be made during the coming season for comparison with St$_1$ and St$_2$.

Trials with St$_2$ varying the supply of nitrogen, phosphorus, potassium, zinc, and boron materially affected spike development, size, and yield, but did not alter the pattern of sterility nor materially affect its percentage.

(*b*) *Systematic Botany.*—The herbarium received many accessions, particularly of New Guinea plants, during the year. To meet difficult problems of accommodation and also to facilitate the use of the specimens for scientific study of the New Guinea flora, the New Guinea material has been separated from that in the general Australian herbarium.

The systematic botanist who is abroad at the Kew Herbarium is revising important groups of Australian plants and preparing a flora of the Australian Capital Territory. She has also arranged for the photographing of many type specimens of importance to Australian botanists as well as of the journals and diaries of Robert Brown. Positive microfilms of some of these manuscripts have already been distributed to some Australian herbaria.

5. MICROBIOLOGY.

(Division of Plant Industry.)

(*a*) *Phytopathology.*—(i) *Studies on Infection Mechanisms Using* Phytophthora infestans.—Inoculation experiments with leguminous plants (*Acacia, Cassia*, and *Erythrina* spp.) showed that the parasite penetrates the leaf epidermis, but is checked by a severe "defence" reaction which is similar to the local lesion reaction known in cereals infested with rusts and some other fungal parasites. Since these legumes are indigenous to semi-arid and arid regions of Australia and have never been in contact with *Phytophthora,* their reaction cannot be the result of "adaptation". This indicates that there are two factors involved in the establishment of a parasitic population: (i) the affinity of the host; (ii) the response of the host tissue to infection. This result throws new light on the mechanism of resistance to infectious diseases.

(ii) *Antibiotics.*—Systemic absorption of streptomycin by both potato and tomato plants was found to lead to a change in reaction of the host to infection by the fungal pathogen, *Phytophthora injestans,* the casual organism of late blight. Streptomycin prevents development of the pathogen *after* infection. Different organs react in different ways and in leaves the effect increases with decreasing age.

The effect on the host is not one which gives general protection against fungal pathogens. Potato plants treated with high concentrations of streptomycin for long periods were heavily infected with powdery mildew. Work planned included studies on other host-pathogen combinations and on the effects of other substances on disease development.

Using tomato plants to study the mechanism of systemic absorption of streptomycin by higher plants, it was shown that streptomycin is readily absorbed from nutrient solutions, and becomes evenly distributed throughout the plant. Phytotoxicity is marked. The severity depends upon concentration, time of exposure, age, and type of tissue. Streptomycin does not appear to be toxic when sprayed at weekly intervals over a period of three months.

Chromatographic analyses of extracts of dried leaf tissue show that a large proportion of the absorbed material is unchanged. Bioassays on the same material indicate physical absorption of streptomycin within the plant.

Further trials for the control of dollar spot of turf established the superiority of P.A.C.A. (phenylaminocadmium acetate) over actidione as a control measure.

(iii) *Plasmoptytic Effects of Sap on Zoospores.*—Sap from potato tubers was shown to contain a chemical factor which causes plasmoptysis of *Phytophthora* zoospores. Investigations of its chemical nature, specificity, and connexion with host resistance have commenced.

(iv) *Electrodiagnostic Studies.*—Tissue of potato tubers infected with *Phytophthora infestans* or *Pythium ultimum* shows a marked increase in conductivity. Conductivity increases immediately *Pythium* establishes contact with the host tissue, but remains normal at this stage in *Phytophthora* infections, the rise in conductivity being significantly delayed.

In tubers interacting with *Phytophthora* in a parabiotic fashion, conductivity rises very quickly after the parasite has established contact with the host cells. This result conforms with previous work on the differences between the reactions of varieties of different resistance to late blight.

(v) *Environment and Disease.*—Observations on the incidence of brown rot of peaches indicate that a factor other than weather is responsible for the great differences between incidence of the disease in adjacent trees. Further observations during the Levis Cling picking season in the Goulburn and Murray River valleys in Victoria suggest that soil moisture differences due to differential absorption of rain-water by sandy soils and loams is the overriding factor. Brown rot is destructive in waterlogged soils, but causes negligible loss in loams with low permeability.

Pot experiments to study the control of take-all of wheat indicated that rotation of crops controlled take-all whereas the addition of some fertilizers did not.

(vi) *Virus Investigations.*—The co-operative programme of assessment of virus chemotherapeutants, reported last year, was abandoned after a tentative bioassay with tomato spotted wilt virus and potato virus X had been devised and given a preliminary trial.

A detailed report was prepared on the experience gained using tissue culture techniques in virus investigation. The potentialities of this field for certain lines of work are considered to be good, its greatest advantage being the possibility of precise control of the environment of the infected tissue being studied.

Nucleus stocks of virus-free potatoes of the varieties Up-to-Date, Katahdin, Sebago, Snowflake and Bismark that had been grown annually in isolation at Paddy's River, Australian Capital Territory, for experimental use, were maintained.

Tubers of the virus-free clone of Green Mountain (Early Carman) potato derived by malachite green treatment as reported previously were planted for multiplication, so that distribution could be made to interested parties.

(*b*) Rhizobium *Research.*—Investigations included a survey of host and bacterial strain variation in symbiosis in subterranean clover and a study of host resistance to infection in *Trifolium ambiguum* and some other species.

(i) *Symbiotic Variation in Subterranean Clover.*—A number of diploid and tetraploid strains of the host have been examined as well as F_2 families derived from crosses between them. Clover strains and individual plants vary in their symbiotic effectiveness and in the number and disposition of the nodules formed upon their roots. Further work will be directed towards genetic analysis of this variation. Tetraploid races of host were found in every instance to nodulate more sparsely than their diploid counterparts.

(ii) *Nodulation.*—Ineffective nodulation in newly established pastures at Deniliquin, New South Wales, was suspected of being a contributory cause of poor clover development. Tests showed that the proportion of ineffective strains present was too small to be of any significance.

Pot experiments at Canberra using undisturbed cores of soil from Armidale showed that the native plant association has no influence on clover establishment. In confirmation of field observations made at the Regional Pastoral Laboratory, Armidale, no ecological correlations were found.

Further work on establishment is to examine the hypothesis that early access of the bacteria to the seedling roots is essential to success. This is being experimentally investigated by artificially delaying inoculation under glass-house and field conditions.

(iii) *Host Resistance.*—Host resistance to infection is of two kinds: (i) resistance to all strains of nodule bacteria; (ii) resistance to strains normally virulent with another host species or group of species. Both types are being investigated by grafting and hybridizing resistants and susceptibles to determine their genetical and physiological relationships. *Trifolium ambiguum* has been chosen to represent the first kind of resistance, and species of *Phaseolus* from the bean and from the cowpea cross-inoculation groups as examples of the second.

All strains of *Trifolium ambiguum* showed poor seed set and some of the crosses made between them were incompatible. It has since been found that these strains form a polyploid series and with this in mind renewed attempts at multiplication will be made in 1954. Some of the *Trifolium ambiguum* strains remained wholly resistant to infection when planted into soil with a rich rhizobial flora, whereas others formed some small ineffective nodules.

(iv) *Bacterial Strain Variation.*—Nodule bacteria differ in host specificity, virulence, and capacity to fix nitrogen in the nodule, all of which are important in the practice of seed inoculation. Experiments are in progress to investigate strain stability during passage through the host plant under laboratory and other cultural conditions. Results obtained show that variation in virulence and effectiveness occurs more commonly than is generally supposed but as yet there is no evidence of any influence of plant passage.

The type culture collection of species of *Rhizobium* is being maintained and extended. Isolations have been successfully made from dried herbarium material sent by plant collectors by air from the Mediterranean and northern Australia.

(v) *The Anatomy of Symbiotic Compatibility.*—In much of the above work the fundamental compatibility of plant and bacteria is involved. Preliminary anatomical and cytological work shows that symbiotic ineffectiveness in subterranean clover does not always arise from premature degeneration of the bacteroid-containing tissue of the nodule as in red clover and some other species. The bacteroids within the infected cells of the nodule have modified cell walls and contain centres of strong oxidizing activity. A comparative study of the nodules of selected lines of red clover, subterranean clover, and burr medic is in progress.

(*e*) *Soil Microbiology.*—The effect of microbial activity on phosphate availability is being examined. Conditions have been determined for optimum acid production by a mixed microflora during the decomposition of carbohydrate in soil. These acids appear to decrease the amount of phosphate retained by a soil high in iron oxide but do not appear to release fixed phosphate from such a soil.

A study of the oxidation of manganese sulphate by soil micro-organisms is continuing. Manganese oxide formed by a soil bacterium has been produced in a chemically defined medium. This oxide has been shown to be an available source of manganese for oats grown in an otherwise manganese-deficient sand culture. Studies of the mechanism of manganese oxidation have shown that a suspension of bacterial cells in distilled water can oxidize a dilute solution of manganous sulphate in five minutes. The effect of heat and various poisons indicate that the oxidation is enzymatic.

6. FRUIT INVESTIGATIONS.

(Division of Plant Industry.)

(*a*) *At Hobart.*—(i) *Physiology of Apple Fruit in Relation to Storage Disorders.*—Most work is centred on a study of the effects of manurial treatment on cell size and physiology in relation to keeping quality. Plots of Jonathan variety are being treated with nitrogen (as urea sprays) alone and in combination with phosphorous and potassium. There are two periods of application, just after petal fall during the period of cell division and in January during the period of maximum cell enlargement.

The response in nitrogen content of fruit to the application in spring is negligible, but the response to the application in summer is substantial with a corresponding decline in colour. The increased nitrogen content is distributed between insoluble and soluble nitrogen. This increase in nitrogen content is reflected in increased insoluble nitrogen content per cell but does not give an increased respiration rate per cell. If the insoluble nitrogen is all protein, the respiration per unit protein is reduced. There has been no indication that the addition of potassium or phosphorous influenced the level of nitrogen absorption or the protein: soluble nitrogen balance.

The effects of adding growth substances in the earlier sprays are being studied. Sprays of the growth substances during the period of cell division increased the cell number per fruit relative to fruit size. In spite of the generally low level of disorder in 1953, there was a parallel reduction in disorder relative to fruit size. This response will allow of further work on the theory that keeping quality is related to relative cell size, which has important implications in relating fruit development to tree nutrition.

The positive correlation between mean fruit size per tree and mean cell size per tree has also been shown to hold for mean fruit size per tree and mean cell size in a fixed fruit-size group.

The general relationships shown in 1952 between cell size and protein nitrogen content; between respiration per cell and protein nitrogen content; between cell volume and incidence disorders; and between protein and soluble nitrogen content, were confirmed in 1953.

(ii) *Gas Storage Trials.*—Gas storage trials with apples in 3–5 per cent. oxygen in the absence of carbon dioxide were continued and have proved successful with a wide range of varieties. There is now sufficient evidence to warrant a semi-commercial trial, which will be carried out in the 1954 season.

(*b*) *At Applethorpe, Queensland.*—(i) *Examination of Cell Number in Apple Fruits.*—Investigations are in progress to discover reasons for the wide variation in cell numbers within apple trees and between trees. This work forms part of the project on the physiology of the apple fruit described in Section 6(*a*) above.

With Granny Smith apples no correlation was found between the time of pollination and cell numbers in the developed fruits. Jonathan fruits borne on single blossom clusters showed variation in cell number and fruit weight; rootstocks M XII, M XVI, and Spy gave the same cell number in Granny Smith fruits.

On one-year-old lateral growths, the fruits produced at the terminal bud were larger, but contained the same number of cells as fruits produced from lateral buds on the same shoot. These terminal bud fruits were also larger than those borne on spurs.

Jonathan fruits from vigorous trees and from trees showing no terminal growth were compared. Cell numbers were similar in both, the difference in size between fruits from stunted trees and from vigorous trees being accounted for by difference in cell volumes.

Mild apple mosaic in Jonathan and canker in Gravenstein had no effect on cell number. Jonathan apples showing boron deficiency symptoms had the same cell number as fruits without symptoms.

Granny Smith fruits from zinc-deficient trees were very small and had a correspondingly small cell number. A 23 g. apple contained 4,000,000 cells and a 64 g. apple from the same tree 13,000,000.

(ii) *Nematode Studies.*—Further studies with the root lesion nematode showed that plots from which infested apple trees had been removed maintained a high-level population when the area was cropped with tomatoes, or allowed to revert to a volunteer vegetation which contained *Rumex acetosella* L. as a dominant species.

Sawdust mulching for nine months to suppress plant growth resulted in a considerable reduction in the soil population of the phytoparasitic nematodes *P. coffeae, Practylenchus macrophallus,* and *Trichodorus* spp.

7. OIL CROPS.

(Division of Plant Industry.)

(*a*) *Safflower* (Carthamus tinctorius *L.*).—Extensive agronomic and breeding studies on this crop were continued at the Waite Agricultural Research Institute and in a number of localities in all States (except Tasmania) in close co-operation with the Departments of Agriculture. These studies have confirmed the great potentialities of safflower as an oil crop under diverse environmental conditions. It stands up well to drought and to both high and low temperatures but yields best under conditions of ample supply of moisture and good soil fertility.

The species *Carthamus tinctorius* L. exhibited a wide range of variability in respect of emergence, early growth habit, degree of spininess, oil content, oil quality, yield, and resistance to diseases. These were utilized in developing new improved varieties which have now been released for yield trials.

A safflower variety was found which, owing to its oil quality and oil components, yields an edible oil. To improve this variety's agronomic properties it was used in a hybridization programme, which is now in the F_3 stage. The material was also used to study the mode of inheritance of oil quality in terms of the iodine number. Studies on the photoperiodic requirements of safflower under controlled light conditions have been commenced.

(*b*) *Linseed.*—In several localities tested selections developed from a cross of Punjab x Walsh appear superior in both oil content and yield per acre to Walsh, which is the common commercial variety. Some of these selections will be released next year.

(*c*) *Castor Bean.*—Studies on introductions of this oil crop were continued and a number of promising types with uniform maturity and low degree of shattering were selected.

8. TOBACCO INVESTIGATIONS.

(Division of Plant Industry.)

(*a*) *Agronomic Studies.*—(i) *Breeding.*—Breeding for resistance to tobacco mosaic was continued and lines have now been selfed. Those showing the necrotic type of resistance in the homozygous condition are being grown for the selection of agronomic types suitable for the north Queensland environment. Because the resistance associated with necrotic spotting breaks down at high temperatures (especially above 97° F.), crosses have been made using the variety Ambalema as the resistant parent. Resistance in this variety is associated with slow multiplication and spread of the virus followed by inactivation within the plant. The Ambalema type of resistance is known to be carried by a double recessive factor.

In a study of the inheritance of the lack
palatability of certain varieties to looper caterpilla
(*Plusia* spp.), resistant plants are being selected in th
F_2 progeny of a cross in which Maryland Mammot
was the unpalatable parent, the F_1 generation havin
been palatable.

Fourteen *Nicotiana* species were tested for susce
tibility to yellow dwarf virus. Five did not develo
symptoms. *N. glauca,* a symptomless carrier of yello
dwarf, big bud, and mosaic viruses, has been crosse
with *N. tabacum* to obtain further information on th
reaction.

(ii) *Diseases and Disorders.*—Soil from Katherin
Northern Territory, retained its ability to cau
"frenching" under glass-house conditions at Canberr
Frenching symptoms appear much earlier at a so
temperature of 35° C. than at lower temperatures an
are delayed by high soil nitrogen. Soil treatmen
with nine trace elements and some major elements d
not have any effect on occurrence but control w
obtained in the glass-house at low soil water conten
Six bacterial isolates from Katherine soil did n
produce frenching symptoms in plants grown ase
tically on nutrient agar or in pots of sterilized so
Filtrates from frenching soil and a washed frenchi
sand retained the ability to cause the disorder.
field tests at Katherine, frenching did not occur
any spray irrigated plots, whereas it occurred in plan
watered by furrows. High ridging of plants al
seemed to reduce the incidence of frenching.

Field observations with trashy leaf showed that
occurred on soils high in organic matter and pa
ticularly where legumes were ploughed in. In southe
Australia it is only a temporary condition but
northern areas it tends to persist and cause loss eve
year.

While blue mould in tobacco seed-beds has bee
controlled for twenty years by the use of benzol, th
has not prevented field infection. Several surveys
field occurrence were made in the Ovens valley distri
of Victoria, where a serious outbreak of blue mou
occurred at about the flowering stage. Infected plan
were not uniformly distributed throughout the distri
nor in individual fields and the reasons for the
differences are to be investigated.

(*b*) *Tobacco Chemistry.*—(i) *Trashy Leaf.*—Fu
ther glass-house studies on tobacco growing indica
that the leaf may deteriorate within a few days aft
addition of nitrogen to the soil. Leaf initially wi
the chemical composition of cigarette leaf does n
"cure out", and remains green after nitrogen trea
ment. Also fluorescence of the underside diminishes
may disappear completely.

(ii) *Curing Properties.*—Good quality leaf may
obtained irrespective of the time required for brea
down of chlorophyll during curing and for full develo
ment of the yellow colour. Leaves of various degrees
ripeness which require 1-8 days for curing could
be of good quality, depending on the initial compositio
Leaves with excessive amounts of nitrogen deteriora
during curing, since as chlorophyll breaks down t
yellow pigments also disappear, leaving coarse, brow
brittle trashy leaf.

(*c*) *Tobacco Physiology.*—(i) *Sucker Control.*—
Seed development and sucker growth both advers
affect leaf yield and quality. Excision of t
inflorescence improves both but unfortunately stimulat
sucker growth. As such growth must be remov
manually at harvest time it is an expensive operatio

Sucker growth has been effectively controlled
applying 2-4 ml of mineral oil to the cut end
each stem when the flowering head is excised. Tria
during the past season in north Queensland ga
70-100 per cent. control. The ratio of trashy to sou

leaf decreases when the sucker growth is controlled and increases when the leaf passes a certain stage of maturity.

(ii) *Water Relations.*—On recovery from a drought, tobacco plants resume growth at a reduced level of water consumpiton. It was observed in the field that tobacco growth occurred intermittently, owing to incipient wilting before an irrigation and complete turgescence just after an irrigation. To test these observations, a pipeline with special nozzles has been installed at Ayr, Queensland, which running continuously will deliver an amount of water equivalent to the periodic irrigations. Tobacco growth under uniform field conditions induced by this mist spray will be studied.

9. GENERAL CHEMISTRY.

(Division of Plant Industry.)

(*a*) *Chemical Techniques.*—(i) *Molybdenum in Soil.*—A method for the determination of molybdenum in soils has been developed. The soil extract is evaporated to dryness and dissolved in hydrochloric acid. Copper, which would interfere with the subsequent determination of molybdenum, is extracted by dithizone in chloroform solution. Molybdenum is then separated from iron by ether extraction of the thiocyanate complex after reduction of ferric thiocyanate with ascorbic acid. After complete removal of ether the thiocyanate is decomposed by digestion with sulphuric acid, and after dilution with water the molybdenum is precipitated as the dithiol complex and extracted into amyl acetate for colorimetric estimation.

(ii) *Sulphates.*—The turbidimetric method for determining sulphate as barium sulphate was studied. Reproducible turbidimetric readings depend upon the production of uniformly sized barium sulphate crystals. This can be achieved by "seeding" the solution with a prepared suspension of barium sulphate which may provide nuclei for the even growth of the test crystals.

(*b*) *Nutrient Availability.*—The availability of soil phosphorus to plants is governed by a number of chemical factors. The more important of these include the pH, the phosphate adsorption capacity, the exchangeable cations, and the soil organic matter. Investigations are being made of the influence of pH and the nature of the exchangeable cation on the adsorption of phosphate when added to soils of differing phosphate adsorption capacity.

Sulphur deficiency occurs over a wide range of different soil types in eastern Australia. Investigations have shown that most of the soil sulphur is associated with the soil organic matter. In pot culture experiments it has been shown that the sulphur utilized by plants is to some extent related to the total soil sulphur. This relationship, however, is poor, and undoubtedly the soil type and other soil factors influence the sulphur availability. Investigation of these factors is continuing.

(*c*) *Fertility Studies.*—A project commenced in 1952 was to study the rate and nature of fertility changes resulting from "pasture improvement" by the use of subterranean clover and superphosphate under conditions of continuous pasture. A survey was made of paddocks with varying top-dressing histories on sandy loams derived from granite in the Crookwell-Binda area, New South Wales. Fertility changes were assessed by the growth and response of oats to applied nutrients in pot culture and by chemical analyses of the soils.

The unimproved soils of the region were found to be seriously deficient in phosphorus, sulphur, and nitrogen. However, the deficiency of each of these elements has been almost fully overcome after a period of 25 years' pasture improvement, during which time a total of 13 cwt./acre of superphosphate was applied. Under this form of agriculture, losses of nutrients through the disposal of farm products is small and it has been found possible to account for all of the sulphur and phosphorus applied to these soils as superphosphate. Practically all of this has remained—even that applied many years ago—in the surface four inches of the soil. As a result of the build-up in soil nitrogen by the legume (subterranean clover) and the accumulation of sulphur and phosphorus from the superphosphate applied, the sulphur, phosphorus, and nitrogen contents of some of these soils have at least doubled since pasture improvement commenced.

It was found that the pH of these soils had decreased under the subterranean clover pastures and further work is in progress to investigate the reasons for this, and to ascertain whether this increase in acidity is likely to have any adverse effect upon plant growth.

The survey has now been extended to two other soil types within the same region—those formed from basalt and of a sedimentary origin respectively. Results so far obtained indicate trends on these two soil types similar to those on the soils of granitic origin. A similar survey of fertility trends resulting from the cultivation of soils for wheat was commenced in the Ariah Park district, New South Wales.

(*d*) *Spectrochemical Investigations.* — Spectrochemical investigations are in progress on differences in cobalt content and uptake between ecotypes of *Phalaris*.

(*e*) *Chemistry of Soil Elements.*—(i) *Manganese.*—Manganese dioxide may be reduced by organic matter of the soil or by microorganisms the more easily the lower the pH. It was found that there was a fourfold decrease in non-biological reduction of manganese dioxide in a soil limed from pH 7 to pH 8. Pot experiments are being carried out on soil from Penola, South Australia, to see how this relationship is reflected in the availability of manganese dioxide at pH values of 7 and 8 respectively.

In parallel experiments on the Penola soil and on another from Rendelsham the relation between the amount of manganese dioxide applied to the soil and the manganese absorbed by oat plants is being studied. The results show that manganese deficiency was overcome by 10 p.p.m. manganese in the Penola soil and 30 p.p.m. in the Rendelsham soil.

An interesting relation was derived from exhaustive plant analysis of both straw and grain. In the more dificient Rendelsham soil, the relation between absorbed manganese and production of straw may be represented by an S-shaped curve. The production of plant tissue shows a relatively greater increase than the absorption of manganese until the point of inflexion is reached. Beyond this (30 p.p.m. added manganese) the formation of plant tissue outstrips the absorption of manganese.

(ii) *Molybdenum.*—Little is known of the chemistry of molybdenum in soils. Two aspects were studied: (i) the solubility of molybdenate in solutions containing iron and aluminium salts; (ii) the constitution (using chemical and X-ray methods) of the synthetic iron and aluminium molybdates so obtained. A naturally occurring iron molybdate was also studied; no naturally occurring aluminium molybdate is reported in the literature.

Further work on the absorption of molybdenum by the clay minerals is under way.

10. PLANT NUTRITION.

(Division of Plant Industry.)

(*a*) *Characterizing Deficient Soils.*—Trials with fertilizers on a number of soils from different areas showed responses to both trace and major elements. The soils examined included samples collected in northern Australia by the Organization's Land Research and Regional Survey Section, as well as samples from southern Australia. The Northern Territory soils showed an acute deficiency of phosphorus, and some also deficiencies of molybdenum and sulphur. Responses to these elements were obtained on the samples from southern Australia.

Soils with an inadequate population of those strains of *Rhizobium* effective on subterranean clover were identified and collected for studying factors concerned in nodulation. Experiments are in progress to define more precisely the limiting degree of soil acidity for satisfactory clover nodulation. In recent years defective nodulation has been recognized as of considerable importance, particularly on the acid podzolized soils.

(*b*) *Availability of Elements in the Soil.*—Considerable progress has been made in the study of the effects of lime on the nodulation of clover. It had been shown previously that normal nodulation and growth of clover could be obtained on acid soils by drilling inoculated clover seed with only 2 cwt. of lime per acre. Current work shows that on all the soils studied the effect of the lime is due to its influence on the numbers of rhizobia in the soil, and furthermore, that this is brought about through the change in soil reaction and not through the increase in calcium supply.

An experiment to examine the effect of clover on the nitrogen status of the soil is being maintained at Canberra. Trials which have been in progress for a number of years on the effects of superphosphate on clover and development of grass will be sown to a cereal to assess the effect of the treatments on soil fertility.

(*c*) *Response to Fertilizers.*—Factors affecting the response to fertilizers are being examined. An important aspect is the study of the interaction between treatments—that is, the effect of one element or treatment on the response to another. For example, studies of the interaction between lime and other treatments have shown that in the majority of the soils examined the effect of lime is due mainly to an indirect increase in the nitrogen supply to the plant. This increase may be brought about through effects on soil nitrification, on molybdenum supply, on numbers of rhizobia in the soil, or on combinations of all three factors. The effects on molybdenum supply and on numbers of rhizobia are usually of much greater importance than the effects on nitrification in the soil.

Further work has confirmed that sulphur may markedly increase the percentage of protein in plants on soils deficient in sulphur, even when the yield response to sulphur is negligible. While rock phosphate may decrease the percentage of protein in clover under conditions of sulphur deficiency, it can increase the percentage of protein when sulphur deficiency is corrected.

(i) *Residual Effect and Form of Fertilizers.*—The need for second and subsequent dressings of fertilizer depends particularly upon the residual effects of the element. A number of field experiments are being maintained to determine long-term residual effects.

The yield responses obtained with rock phosphate applied at levels comparable with superphosphate have been small under all of the conditions examined. Studies with rock phosphate and field trials will be maintained for several years to examine subsequent effects.

(ii) *Uptake of Elements by Plants.*—It is known that the uptake of a particular element by plants may in some instances be markedly affected by the uptake of others. This is distinct from the effect of treatments on the availability of elements in the soil. Work has been commenced to critically examine the effects of varying levels of each of the elements on the uptake of others.

(*d*) *The Role of Elements in Plants.*—(i) *Plant Composition.*—A study of the effects of deficiencies of essential elements on the amino acid composition of plants was continued. The results show a lower amino acid content under conditions of molybdenum deficiency. A quantitative estimation of the amino acids present under the different conditions is being made.

Further evidence on the role of molybdenum in nitrogen metabolism has been obtained. It was found that the nitrate and ammonia content of the tops of tomato plants was doubled four hours after supplying molybdate to the molybdenum-deficient plants. In the intact plant molybdenum is essential for a reaction involved in the reduction of nitrate to nitrite.

Molybdenum also affects phosphorus metabolism, although it is not known to what extent this function is specific. The application of molybdenum to the culture medium markedly increased the concentration of organic phosphorus in the plants within two days, and correspondingly decrease the concentration of inorganic phosphorus.

(ii) *Biochemical Reactions.*—Further evidence on the effect of molybdenum on phosphatase activity was obtained. Tests with various substrates showed that all except glucose 1-phosphate were hydrolysed by tomato leaf acid phosphatase preparations, and that in all substrates hydrolysis was inhibited by molybdate. It was found posible to measure the *in vivo* phosphatase activity of intact living roots by immersing them in a solution of *p*-nitrophenyl phosphate, and measuring the rate of formation of *p*-nitrophenol. As molybdate, at physiological concentrations, inhibits phosphatases *in vivo*, inhibition of phosphatases may be an important metabolic function of molybdenum.

11. Mineral Nutrition of Plants.

(Division of Biochemistry and General Nutrition.)

These studies especially concern the relatively minute but essential requirements that plants have for the heavy metals, zinc, copper, molybdenum, &c.

Field experiments which focused attention on the importance of these micronutrients and which initiated the spectacular development of the Coonalpyn Downs, South Australia, have defined overall problems, and in turn have revealed many lacunae in our knowledge that may best be filled by experiments under the controlled conditions of the laboratory and glass-house. Experimental studies have been initiated to throw further light on the morphological and metabolic lesions which occur in certain fodder species grown under conditions in which the mineral requirements are not fulfilled. The various techniques have been perfected to a stage where many of the outstanding questions may be answered. Special attention is now being given to the morphological lesions, since a better knowledge of these is essential for the solution of many of the practical problems encountered during development of deficient terrain. The work is proceeding.

12. Plant Toxicology.

(Division of Plant Industry.)

(*a*) *Evaluation of New Herbicides.*—Additional compounds synthesized by the New South Wales University of Technology have been tested for use as herbicides. This work has shown an error in the conventional split pea test for auxin activity.

(*b*) *Mistletoe Investigations.*—These have been continued in collaboration with the Commonwealth Forestry and Timber Bureau, with a view to finalizing the determination of the optimal doses of 2,4-D, and the doses possibly required for a second application for the control of mistletoe. Tests with 2,4-D derivatives are also proceeding.

(*c*) *Impedance Measurements.*—Apparatus has been designed so that measurements up to 2 Mc/s can be made. With the improved electrodes it is posible to obtain constant impedance measurements over an hour. Emphasis is being given to such measurements, as they are valuable for determining the degree of injury to plant tissue resulting from either a pathogen or a poison.

Impedance measurements have been made on healthy and infected potato tubers. These clearly show whether the tissues are injured or uninjured. Injury or its absence depends on the type of fungal pathogen and on the variety of potato.

Further measurements of phase angle on potato tubers have been made in relation to diagnosing the presence of viruses. The degree of significance between healthy and infected batches can vary with maturity. It was shown that the difference in phase angle between the two ends of a tuber may indicate the presence or absence of leaf roll virus.

13. PLANT PHYSIOLOGY.

(Division of Plant Industry.)

Most of the work has continued to be centred around problems of plant development.

(*a*) *Long-day Plants.*—More interest attaches to the development of plants of this type, since they include most of the plants of southern Australia of economic significance. However, critical work can only be carried out in an accurately controlled environment (obtainable with such equipment as was described in the last Report). Efficient use of such facilities requires test plants which are both small and easily cultured, and with a rapid life cycle. Out of many species tested *Anagallis arvensis* L. is proving most satisfactory. It is very sensitive, requiring only two or three exposures to long day for flower initiation. The response is rapid, flowers being initiated at the second node, and they are microscopically determinable 15-18 days after germination.

(*b*) *Phalaris tuberosa.*—In certain districts *P. tuberosa* grows unsatisfactorily the year following its establishment, and there is evidence that this is related to the conditions of its summer dormancy. A trial to ascertain the effects of temperature and length of day on the development of *P. tuberosa* has been started, and this will be continued for a period after the first season's dormancy.

(*c*) *Auxin Relationships.*—Application of α-naphthaleneacetic acid and β-indoleacetic acid has been shown to delay flower initiation in *Malcomia maritima,* a long-day plant. No effect was observed with the anti-auxin 2,3,5-tri-iodobenzoic acid.

(*d*) *Stem Tip Culture.*—A new approach to the study of the effects of micronutrients on plant development is being sought by culturing microscopic fragments of stem tips on artificial media, under which circumstances the internal *milieu* may be more effectively altered by selected addenda. Fragments consisting of an apical meristem and two leaf primordia, and approximately 200 μ long, have been successfully cultured. Results from the application of auxins and anti-auxins suggest that such explants do not necessarily continue growth with the potential and pattern appropriate to the physiological age of the plant of origin, but may revert to a juvenile stage. Attempts are being made, using the above technique, to culture inflorescence primordia of the basal sterile speltoid wheat St_2 to study the physiology of sterility.

(*e*) *Nitrogen Metabolism of Legumes.*—It is known that amides occupy key positions in the nitrogen metabolism of plants, and currently it is held that either asparagine or glutamine plays a preponderant role in different plant species. Members of the Leguminosae are regarded as asparagine plants. Some evidence on this has been obtained using the technique of embryo culture, under such conditions that embryo growth may be regarded as a measure of protein synthesis. Contrary to the established view, glutamine has proved superior to asparagine as a source of nitrogen for the growth of isolated embryos of *Medicago tribuloides.* The full quantitative relationships between asparagine and glutamine are now being established for a range of leguminous and non-leguminous embryos.

14. PLANT ECOLOGY.

(Division of Plant Industry.)

(*a*) *Regional Vegetation Surveys.*—Surveys for the purposes of classifying and mapping plant communities are proceeding in the Southern Tablelands, Macquarie, and New England regions of New South Wales, and in the rain-forest regions of Queensland and northern New South Wales. A survey in south-western Queensland was completed and the one in New England will be completed this year. The climate-plant-soil interrelationships established by such surveys will be utilized in the pasture improvement research programme of the Division.

(*b*) *Studies on Native Grasslands.*—(i) *Treeless Grasslands.*—Ecological studies of the subalpine grasslands of the Monaro region, New South Wales, are continuing. During the past twelve months, records were taken of soil and air temperatures and water-table heights at the experimental site on Seventeen Plain. A preliminary survey of the grasslands at higher altitudes has been made in co-operation with the Soil Conservation Section of the Snowy Mountains Authority.

(ii) *Grazing Management Experiment, Trangie, New South Wales.*—This project, which is being conducted in co-operation with the New South Wales Department of Agriculture, is designed to obtain information on the management of semi-arid *Stipa-Chloris* pastures. The effect of different stocking rates and systems on the yield and persistence of the perennial grasses and the wool production and live weights of Merino wethers has been studied for more than five years without positive results. Consideration is being given to a modification of the design, using various proportions of lucerne with native pastures.

(iii) *Autecological Studies on Native Grasses.*—Life history studies of some native perennial grasses and winter annuals have been completed. Investigations of the soil-plant-moisture relationships of native grass species on different soil types has commenced at Trangie, New South Wales. On the Southern Tablelands of New South Wales a study is in progress of the incidence of red grass, *Bothriochloa ambigua,* in the native *Danthonia* pastures.

(*c*) *Ecological Studies on Contiguous Woodland Communities.*—A study of the habitats of two different but contiguous woodland communities in the Australian Capital Territory was commenced. The communities are *Eucalyptus polyanthemos* and *Eucalyptus meliodora* and initially the work is being restricted to soil factors.

(*d*) *Ecology of Rain-forest.*—Studies of the distribution of rain-forest and of the hydrologic cycle of the rain-forest formation have commenced in northern New South Wales and Queensland. The study aims at determining the environmental requirements of commercially valuable rain-forest timber species for maximum wood production. Physical measurements of the microhabitat are being made at monthly intervals in the Whian Whian State Forest, New South Wales. These micro-environment studies are relevant to problems of silviculture and natural regeneration of timber species.

(*e*) *Ecological Studies on Weeds.*—(i) *Skeleton Weed* (Chondrilla juncea).—Competition between introduced pasture plants and skeleton weed continues to be studied at Cowra, New South Wales, and Canberra. Subterranean clover is still the most effective competitor of the species tested, but competitive effects have not been severe because of the dry weather experienced, which favours the weed rather than the pasture species.

(ii) *Hoary Cress* (Cardaria draba).—The effect of competition from pasture species on the growth of hoary cress is under study at Murtoa, Victoria. In the first year, Wimmera ryegrass (*Lolium rigidum*) was much more competitive than barrel medic (*Medicago tribuloides*).

(iii) *Distribution of Introduced Weeds in South-eastern Australia.*—In Victoria the distribution of introduced weeds in relation to climate, soil, and land use is under study.

(iv) *Ecology of Aquatic Plants.*—This work, which aims at determining the factors concerned in the establishment of various species of aquatic weeds in the Murrumbidgee Irrigation Areas of New South Wales, has been in progress for just over a year, but as yet it has not been possible to establish clear relationships between channel characteristics and their weed populations.

15. PLANT BIOCHEMISTRY.

(Division of Plant Industry.)

(*a*) *Morphogenesis in Plants.*—A programme was initiated on certain aspects of the biochemistry of morphogenesis in plants, particularly the induction mechanisms underlying the formation of a new meristem during regeneration and its subsequent mode of differentiation, and three approaches have appeared most fruitful:

(i) Fragments of hypocotyls of flax seedlings and other species were cultivated aseptically on the surface of chemically defined media. Excision resulted in the formation of buds and roots adventitiously, the new bud meristems arising from adventitious divisions of mature epidermal cells. The addition to the medium of minute quantities of chemical analogues of purines, pyrimidines, or their metabolic precursors strongly inhibited the formation of new buds and roots.

(ii) By means of coconut milk extracts and auxins, sterile cultures of undifferentiated callus tissue have been produced and clones derived from single individuals are being built up. Conditions in the physical and chemical environment which will induce various kinds of redifferentiation are being studied.

(iii) Certain species sucker from the roots when decapitated while others do not. Seed has been obtained of strains of tomato and lucerne which do sucker while strains closely related to them do not. The biochemical differences between these two types (e.g. the presence of a factor essential to regeneration in the one, or an inhibitor of it in the other) are being studied by cultivating isolated root tips of each strain aseptically and performing cross-feeding experiments from one strain to the other.

The need for rapid nucleoprotein synthesis and energy transfer in a region of active cell division, and the inductive effects of certain nucleotide precursors and the inhibitory effects of their analogues, are receiving particular attention. Analytical and enzymatic techniques have been developed for studying certain reactions incorporating simpler precursors into the nucleotides and nucleic acids of flax hypocotyl material.

(*b*) *Enzyme Studies.*—The programme of work in collaboration with the Biochemistry Department of the University of Melbourne includes a study of the cytochrome components and electron transport system in yeast and higher plants.

During the past year the enzyme " yeast lactic aci dehydrogenase " or cytochrome b_2 has been studie in detail, and has recently been crystallized. Th crystalline enzyme has been shown to contain bot flavine and haem as prosthetic groups.

Further physical, chemical, and kinetic studies o this enzyme are in progress.

16. PHYTOCHEMICAL SURVEY.

(Division of Plant Industry.)

Since the appearance of the Report for 1951-52 th Division has continued its participation in the re organized Phytochemical Survey, in collaboration wit various Australian and overseas universities, th Queensland Herbarium, and the forestry authoritie of Queensland and New South Wales.

About 180 bulk samples for chemical and pharma cological analysis were collected, mainly by the Stat forestry authorities. A limited number of bulk sample as well as preliminary samples for screening in othe laboratories, was collected by the Division. Liaiso between the co-operating groups, vital records, and th botanical advisory function have been maintained.

Co-operative projects between the Division and over seas institutions include: search for tumour-damagin plants (with Sloan Kettering Institute for Cance Research and National Institute of Health, Unite States of America); steroidal sapogenins (Universit of Basle, Switzerland); screening of plants reputed t cause temporary sterility in native women (with Co trolled Fertility Research Centre, England); investiga tion of wannakai (*Rhodomyrtus macrocarpa*), allege to cause blindness in humans (with Universities Cambridge and Leeds, England); and investigation native medicinal plants (with Administration Papua-New Guinea).

Preparations from several Australian plants pr duced damage in experimental sarcoma 37, and a being further investigated in American laboratorie Crystalline compounds were obtained from *Rhod myrtus macrocarpa*, and their specific toxicity is bein studied in English laboratories.

Co-operative projects between the Division and othe Australian institutions include the study of live-stoc poisons (with Division of Industrial Chemistry an Division of Animal Health and Production); surve of cardiac glycosides (with Pharmacology Departmen University of Sydney); screening of higher plants f antibiotics (with Bacteriology Department, Universit of Adelaide); and general phytochemical investigatio (with Chemistry Departments of Australian unive sities).

Many promising plants have been revealed by t exploratory work of the Division. These plants a being collected. As a consequence, numerous com pounds of potential pharmacological and industri value have been characterized. These include dryin oils, alkaloids, antibiotics, lignanes, cardiac glycoside and other substances.

17. PASTURE INVESTIGATIONS, CANBERRA, AUSTRALIA CAPITAL TERRITORY.

(Division of Plant Industry.)

(*a*) *Species and Strain Investigations.*—(i) *Su terranean Clover.*—In studies of the 60 strains collecte in the Mediterranean area in 1951 there was a relatio ship of type to area of origin. Material collected Palestine and Morocco was in the early maturity grou whereas that from north-west Greece was in the la maturity group. However, material collected within adius of a chain or so in an apparently uniform nvironment often showed considerable variation in lowering dates and morphological characters. Comparison of Australian and Mediterranean material howed morphological and physiological differences. The most clear-cut of these differences was the more requent red coloration of the calyx in the Australian opulation and the greater susceptibility to frost of oastal Moroccan material.

(ii) *Annual Medics.*—All field trials with medics ave shown that the *tribuloides* group is generally more uitable than other species under New South Wales onditions. A very productive strain, *Medicago tribuloides* No. 173, has been brought into the seed certification scheme of the New South Wales Department f Agriculture, and should be available commercially y the end of 1954.

A close relationship was shown between dehydration f medic seeds and the development of impermeability f the seed coats to water. Studies of the factors oncerned in the production of hard seeds by medic pecies are under investigation. Experiments to neasure productivity of medics under sward conditions re in progress at Wagga, Temora, Crooble, Condobolin, nd Trangie, New South Wales. At Wagga and Temora medics have not compared favorably with subterranean clover and this appears to be due to the ailure of the medics to actively fix nitrogen. Field esponses to molybdenum have been obtained at both f these centres. Studies to date suggest that medics ave a higher molybdenum requirement than subterranean clover. Drought conditions at Trangie and ondobolin have upset sward trials for two years in uccession.

(iii) *Grasses.*—*Phalaris tuberosa* has yielded significantly better in 21-in. and 35-in. spaced rows than in -in. rows at the Dickson Experiment Station. The ffects of nitrogen and soil moisture on these results re being examined. Studies of the effect on total production and growth rhythm of *Phalaris tuberosa* and ubterranean clover when other species of grasses are ntroduced into the mixture are in progress. Results to ate show that the ratio between *Phalaris tuberosa* nd its associated species has varied according to the ssociated species used.

The productivity of special purpose pastures for roviding forage at different seasons of the year is nder investigation. The influence of phosphorus and itrogen levels on the persistence of perennial ryegrass s also under examination.

(*b*) *Fertility Studies.*—(i) *Fertility Lift by Subterranean Clover.*—The effects of improved pastures on oil fertility are being investigated. Fertility as neasured by productivity can be increased by applying uperphosphate to subterranean clover pastures. The ffects of this procedure on the status of nutrients ther than phosphorus are being examined.

An exploratory survey has been undertaken in the heat belt near Temora, New South Wales, to determine the effect of continued wheat cropping on red-brown earth soils.

(ii) *Influence of Pasture Species.*—Attempts to ollow changes in soil structure under pure stands of ubterranean clover, red clover, lucerne, *Phalaris uberosa*, perennial ryegrass, and Wimmera ryegrass ave not been successful, as no successful method of neasuring soil structure has been found. The long-term experiment designed to determine the influence of olunteer pasture, subterranean clover, and a mixture f *Phalaris tuberosa* and subterranean clover for arious periods of time on soil fertility measured in erms of subsequent wheat yield is continuing at the ickson Experiment Station.

(*c*) *Pasture Utilization.*—Fluctuations in the growth of pasture which is the basis of animal production result in periods of insufficiency, adequacy, and excess of feed for a relatively constant animal population. Stocking rates are limited primarily by the length of the period of shortage, so that greater utilization of young growth in periods of excess cannot be achieved by increasing stocking rates alone. Growth in a *Phalaris*-subterranean clover-lucerne pasture at Canberra that was neither consumed, nor conserved while green, rapidly lost its value as animal fodder. However, by conserving excess material in the spring not only can the periods of deficiency be provided for but a substantial increase in stocking rate appears feasible on the evidence to hand. Slight increases in wool yield, double liveweight gains, and increased proportion of first grade to lower grade mutton have been obtained.

Comparisons of areas from which excess spring pasture was removed in the previous spring and not fed back, with areas where no conservation was practised, showed that after a comparatively dry summer and autumn the body strike by blowflies was considerably less in the first areas. Secondly, in the winter and spring the incidence of "Phalaris staggers" was considerably less on the former areas. Thirdly the liveweight gains in winter and spring were greater on the former areas. Studies are being made on the factors concerned in the management practices that brought about the pasture quality changes which had such a marked advantage over pasture quantity characteristics in improving the health and production of sheep. This work is being extended to measure the effects of high utilization using various pastures and in relation to different forms of animal production, for example, mutton, wool, and beef, separately and together.

(*d*) *Management.* — (i) *Conservation.* — Various degrees of pasture conservation are being compared in a long-term experiment in which five equal areas are each carrying the same number of sheep continuously, but in four of the areas various proportions are harvested during the spring for fodder. The sheep are then maintained on the herbage production from the balance of each area until such time as their body weight indicates that they are getting insufficient feed, when the conserved fodder is fed back to them as required.

(ii) *Conservation Effect on Pasture.*—Surplus green growth is taken off for silage or for hay and the regrowth of the pasture the following year is related with the method of conservation and its productivity.

(*e*) *Nutrients and Light Competition.*—Studies of the competition between pasture species for light and nutrients were continued. An experiment with *Lolium perenne* and *Phalaris tuberosa* showed that competition for light and nitrogen interacted when other nutrients and water were supplied in non-limiting amounts. Thus competition for light was more marked in the presence than in the absence of competition for nutrients.

18. PASTURE INVESTIGATIONS, ARMIDALE, NEW SOUTH WALES.

(Division of Plant Industry.)

(*a*) *Ecological Surveys.*—(i) *New England Region.*—This survey involves the investigation of all the inherent land characters that affect agricultural utilization of the land. These include climate, soils, geology, topography, and natural vegetation. The main aim of the survey is to define and evaluate the various environments that occur within the region, primarily in connexion with their suitability for the growth of sown pastures. This work should be completed by the end of 1954.

(ii) *South-western Queensland.*—The detail mapping of vegetation association complexes and great soil groups has been completed in the area selected as representative of the larger area under survey.

(*b*) *Autecological Studies of Native Pasture Species.*—The life cycle of each species studied is being recorded and the precipitation : evaporation ratio necessary for plant growth on each pasture type is being calculated. Observations on the effect of burning at monthly intervals throughout the year have shown that the overall effect was a 50 per cent. reduction in the basal area of the grasses, and a small increase in the basal area of rushes and sedges.

(*c*) *Grazing Management Studies of Native Pastures.*—The long-term experiment on the comparison of rates of stocking, and of continuous grazing with rotational grazing, has been completed.

In co-operation with the Division of Animal Health and Production (*see* Chapter III., Section 21) a study has been commenced on the effect of supplementing the grazing of a breeding flock of Merinos on native pasture with different percentages of sown pasture. The first year's results have shown that even with small percentages of sown pasture (less than 20 per cent.) it is possible to breed Merino sheep. On native pasture alone it is generally impracticable to breed Merino sheep, even at light rates of stocking.

The aftermath from summer production on native pastures is considered to be partly responsible for poor winter production. A study is being made of the effects on winter production of reducing this aftermath by varying the summer stocking rate of sheep, using both cattle alone and cattle in conjunction with sheep, burning, mowing, and incorporating clovers. The winter liveweight gains were greatest on the clover-treated areas; next highest on the pasture left unstocked during the previous summer.

(*d*) *Improvement of Native Pastures.*—The establishment of clovers into dense native pastures without ploughing has been successful, and has improved the normally low protein content of the native grasses and also their forage value. The persistence of many native grasses in competition with clover, however, was reduced. Surface seeding of sown grasses to supplement the native species is now receiving attention.

(*e*) *Species and Strain Trials.*—The testing of pasture species is being expanded and extended into new areas. Notwithstanding drought conditions during the year 1954, a number of grasses yielded as well as or better than *Phalaris tuberosa* and some produced more protein per acre. Possible development of seasonal pastures to provide year-round grazing is envisaged.

(*f*) *Plant Nutrition Studies.*—The survey of the plant nutrient status of New England soils has been extended to ten of the major soil types. Podzolic soils are generally deficient in phosphorus, while basaltic soils respond mainly to nitrogen. The deficiency of sulphur or phosphorus in basaltic soils is less severe. No evidence of a potassium, magnesium, or trace element deficiency was observed in any of the soils tested. A new project, to examine the factors involved in the greatly improved growth of *Phalaris* pastures following renovation by ploughing down, indicates that if nutrient release following the cultivation is implicated, the nutrient mainly concerned is probably nitrogen, with sulphur playing a minor role.

(*g*) *Clover Nodulation.*—In conjunction with the School of Agriculture, University of Sydney, some of the difficulties associated with the nodulation of clovers have been overcome by the isolation and identification of superior strains of the root nodule bacteria. Satisfactory strains are now available for subterranean clover, crimson clover, and red clover.

19. PASTURE AND HYDROLOGY INVESTIGATIONS, DENILIQUIN, N.S.W.

(Division of Plant Industry.)

(*a*) *Ecology.*—(i) *Native Pastures.*—Studies on root concentration and chloride content in the *Danthonia caespitosa* grassland and the *Atriplex vesicaria* saltbush indicated the control of species by soil salt concentrations. The growth of grasses in the *A. vesicaria* community was limited by high chloride concentrations in the 3-9 inch depth (0.23-0.43 per cent.). The winter growing grasses could make only limited use of soil moisture in the reliable rainfall period (winter), and the considerable residue of available moisture was utilized by *A. vesicaria* in the warmer period of the year.

Phenological studies on plant species of the *Danthonia caespitosa* grassland have resulted in the recognition of two distinct groups: autumn germinating-spring flowering, and autumn or spring germinating-warm season flowering.

The grazing trial on *Danthonia caespitosa* grassland has been continued. Seedlings which germinated subsequent to the winter of 1952 now constitute the majority of plants, and are increasing in basal area.

The main edaphic factors influencing species distribution in the gilgai microrelief appear to be: (i) the ability of surface soils to absorb and transmit water to the subsoil; (ii) the ability of the subsoil to retain available moisture; (iii) the effect of soil structure on root distribution; (iv) the effect of subsoil salinity; (v) the effect of inadequate aeration induced by water-logging.

The maximum depth of uniform wetting under natural rainfall varied from 12 to 24 inches depending on soils. This may explain why semi-arid vegetation is characteristic on these soils, and indicates the difficulties in introducing and maintaining more productive pasture species.

(ii) *Irrigated Pastures.*—Determinations of soi moisture, porosity, and air space of a heavy clay soi were made during and subsequent to a period of low winter production in a subterranean clover (*Trifolium subterraneum*)-Wimmera ryegrass (*Lolium rigidum*) irrigated pasture. It is suggested that this poor growth is not a consequence of low temperature, but is an expression of the inadequate air space at the high moisture content found in these swelling soils after late autumn irrigation, followed by winter rains and low evaporation and transpiration rates.

(iii) *Population Dynamics.*—Principles have been developed for the construction of a consistent mathematical treatment of the various problems of population dynamics, attention so far being directed to the problem of interspecific competition. Three types of interspecific competition have been distinguished: "imperfect " "perfect ", and "hyperperfect ", depending on the value of the product *a* in the Lotka-Volterra equations Simplifications of the normally quoted inequalities and limits resulting from these equations occur when competition is perfect, as it will be in many instances of importance to natural selection and evolution "Metabolic efficiency " is as important as "reproductive efficiency " to the survival of the species.

The properties of an "asocial " sexual species in which the individuals move in a random manner have been considered and compared with those of a "social " population in which sparsity of population does no limit reproductive opportunity. A "population phase diagram " is developed which represents the equilibrium states the asocial population will assume, according to the favorableness of the environment and the initia population density. Kinetic aspects have also been examined and conclusions reached as to the selective advantage conferred by sociality and the conditions under which inoculation of an environment with an asocial organism will be successful.

(*d*) *Plant Species and Strain Trials.*—In 1953, when late rains limited growth to winter and spring, *Lolium rigidum* and *Trifolium hirtum* outyielded other introduced dryland species. Selections were made from 130 irrigated species and strains which had been grown in rows or small plots for three years. Promising new material includes strains of *Phalaris coerulescens, Festuca elatior, Poa iridifolia,* and *Medicago soleirolii* for areas irrigated in autumn and spring, and *Panicum coloratum* for areas irrigated during summer.

(*e*) *Behaviour of Alkali Clays under Irrigation.*—Gypsum dressings did not improve the yield of Wimmera ryegrass-subterranean clover pasture in its second year of growth, although they increased soil porosity. The growth of rice as a pretreatment crop improved the establishment of Wimmera ryegrass, but did not affect the yield of either ryegrass or subterranean clover in their second season.

Irrigation of summer growing pastures for several years has not permanently reduced the chloride content of the top foot of soil.

Exposure of the surface of an alkali clay allowed the destruction of water-stable aggregates by rain or irrigation water, but flood irrigation did not reduce aggregation where a pasture cover was present.

(*f*) *Plant Nutrition.*—A pot trial using grey clay soil and sandy loam soil taken from areas which had been under native pasture, and from other areas which had been under fertilized irrigated pasture for six years, demonstrated that—

(i) "Krilium", while greatly improving the aggregate stability of both loam and clay soils and reducing the mass shrinkage of the latter, depressed yields on the clay soils and increased them slightly on the loam soils. The effects of "Krilium" were more marked on soils which had not been irrigated.

(ii) The virgin clay soil outyielded all others, even though the irrigated soils had received from 12 to 24 cwt. of superphosphate in the previous six years.

The soils which had grown irrigated pastures for six years had accumulated a surface horizon of undecomposed plant material which had been removed before potting. This material (about 5 tons/acre) held the equivalent of 12-cwt./acre of sulphate of ammonia and 4-6 cwt./acre of superphosphate.

(*g*) *Hydrology.* — (i) *Irrigation Hydraulics.* — Studies of the hydraulics of surface methods of irrigation have led to work on the hydraulic properties of soil surfaces and vegetative cover. A flume of adjustable slope is being designed for the measurement of these properties.

(ii) *Mathematical Physics of Water Movement in Soil.*—Theoretical studies have resulted in the development of simultaneous partial differential equations describing the movement of liquid, vapour, heat, and solutes in a soil of stable structure. Solutions of these equations for particular boundary conditions describe the movement of water, heat, and solutes during the course of such phenomena as infiltration, drainage, and evaporation from soils, and can also add to the understanding of such concepts as "field capacity" and "wilting point". Work to date has dealt mainly with infiltration, the solutions secured giving soil moisture as a function of time and depth.

(iii) *Field Capacity.*—It was shown experimentally that the "field capacity" as commonly defined varies with the depth of water applied. This result has been confirmed by mathematical-physical studies.

(iv) *Evaporation.*—Preliminary measurements have been made of evaporation from soil columns with water held at a range of depths. Saline and non-saline water-tables were used. Evaporation from the saline columns was less than from the non-saline, the discrepancy increasing as the salt concentration near the surface increased with time.

A somewhat simplified mathematical analysis of the physics of evaporation from soils has given a relationship between evaporation rate and water-table level which agrees with this experimental result. It is predicted that, in evaporation from an initially saturated soil column (no under-drainage), a period of constant evaporation is followed by one of decreasing evaporation. This has often been observed experimentally, but does not seem to have been previously deduced by quantitative physical analysis.

(v) *Vapour Movement in Soils.*—Experimental studies of isothermal water vapour movement in a sandy soil indicate that the simple theory of vapour diffusion in porous media proposed by Penman holds reasonably well.

(vi) *Irrigation Probe.*—This work is being extended over a wider range of soil moisture, using a new penetrometer of hydraulic type.

20. PASTURE INVESTIGATIONS IN WESTERN AUSTRALIA.

(Division of Plant Industry.)

(*a*) *Grazing Management Experiment, Perth.*—This experiment, involving a comparison between continuous and autumn deferred grazing on a subterranean clover pasture, has been in progress since 1949. A consideration of the results suggests that 2⅔ wether sheep per acre approaches the maximum for annual pastures in the Perth environment. Towards the end of the 1953-54 summer period, loss in sheep weight was greater under continuous grazing than with deferred grazing, thus confirming results obtained earlier. Under deferred grazing *Bromus rigidus* was the dominant grass species, while under continuous grazing Wimmera ryegrass was dominant. There was no difference in the proportions of clover and cape-weed on the two treatments.

(*b*) *Grazing and Rotation Experiment, Wongan Hills.*—This experiment, which is being conducted in co-operation with the University's Institute of Agriculture and the State Department of Agriculture, was commenced in 1946 and with the completion of the second 4-year cycle has now been terminated. Two points have been definitely established: (i) the significantly rapid build-up in soil fertility under subterranean clover and to a lesser extent with lupins in a pasture-pasture-pasture-wheat rotation; (ii) the detrimental effects on soil fertility of continuous cropping with oats.

(*c*) *Species and Strain Investigations, Kojonup.*—(i) Phalaris tuberosa.—The study on the effect of row spacing on yield and persistence of this species was continued. Last year's data confirm the beneficial effects on yield per unit area of wide spacing (35 and 49 inch) as compared with narrow spacing (7 and 21 inch), and also the increased yields from inter-row cultivation.

An experiment to examine the effects of nitrogen fertilizers and increased water supply has just commenced.

(ii) *Other Pasture Grasses.*—Studies on four perennials, *Phalaris tuberosa, Ehrharta calycina, Oryzopsis miliacea,* and *Hyparrhenia hirta* commenced in 1954. More comprehensive trials with other grass species are being designed for 1955.

(iii) *Subterranean Clover.*—A sward trial involving fifteen strains, initiated in 1950, was continued. Results from 1953 confirm the marked superiority of the two strains Leeds and Hill's Small over the commercial Dwalganup strain for spring production. Several years' data from single spaced plants indicate a linear relationship between time of maturity and yield of total tops and seed.

(iv) *Cereals.*—Variety trials with wheat, oats, and barley were continued. Wheat grain yields, in contrast to previous years, showed no significant effect of earliness of maturity; differences between individual varieties were small. A number of oat and barley varieties will be tested for winter production and grain yields in 1954.

(*d*) *Plant Nutrition Studies.*—(i) *Pot Culture Experiments, Perth.*—Studies on factors affecting zinc response in subterranean clover have been continued. Response to applied zinc depends on the percentage of total phosphorus in the plant tops. This effect appears to be due to reduced efficiency of utilization of absorbed zinc rather than reduced absorption of zinc *per se.*

(ii) *Field Experiments, Kojonup.*—The influence of seasons on zinc response in three strains of subterranean clover is being examined. It is hoped to relate differences in the response obtained from zinc applications in 1952 and 1953 to rainfall, light energy, and temperature. The effects of varying initial rates of application of both superphosphate and rock phosphate on a clover pasture were examined over a two-year period. A marked growth response from rock phosphate was found in subterranean clover, but not in volunteer cape-weed. The phosphorus recovered in the pasture over the two years was much higher from superphosphate than from rock phosphate. Annual dressings of superphosphate are being compared with single heavy initial dressings.

Studies with sulphur are continuing. All responses so far have occurred on land not recently cultivated. The relationship between cultivation and sulphur response is under study.

(*e*) *Soil Fertility Studies, Kojunup.*—Preliminary results from several long-term projects commenced in 1952 outlined in last year's Report should be available next season.

(*f*) *Ecology of Annual Type Pastures, Kojonup.*—These studies are concerned with the factors affecting changes in botanical composition in annual type Mediterranean type pastures, and in particular the effects of seasonal conditions. It was demonstrated that increasing phosphate level is associated with a decrease in the percentage contribution of *Erodium botrys* and an increase in cape-weed. The percentage of subterranean clover rises or falls with phosphate up to moderate levels, but invariably decreases at high phosphate levels, presumably due to competition from cape-weed. Further studies of changes in botanical composition on clover pastures were initiated in 1953.

21. Pasture Investigations in South-eastern Queensland.

(Division of Plant Industry.)

(*a*) *Coastal Lowlands.*—(i) *Ecological Survey.*—The ecological survey of the coastal lowlands of south-eastern Queensland, popularly known as the "wallum country", was continued. The whole area forms a narrow coastal plain of gently undulating topography, scarcely anywhere exceeding 300 feet above sea-level. This study is being used to plan and locate detailed projects on the nutrient deficiencies of the soils within the region, and to give a wider basis of application of the results of experiments with pasture species and mixtures in progress.

(ii) *Pasture Species and Mixtures.*—The eucalypt forest and the tea tree forests occupy the greatest areas of the coastal lowlands and four sites 40 and 50 miles north of Brisbane have been selected for field experimentation—two in the eucalypt forest, Elimbah and Beerwah, and two in the tea tree forest, Beerwah and Glasshouse.

Subtropical and tropical grasses and legumes are being tested in grass-legume mixtures, but some testing of temperate species is also done. Grasses of the genera *Paspalum* and *Panicum* are giving the best results, but several other species, notably *Brachiaria purpurascens* and *Pennisetum clandestinum*—the latter in the peaty tea tree soil at Glasshouse—have given good yields and persistence. A number of useful grasses can be grown provided adequate nutrient supplies are ensured. The soils are acutely deficient in nitrogen, and especial attention is being given to the legume components of the pastures.

The low nutrient status of the soils is the critical limitation in the growth of legumes, but the prevalence of nematodes, of the bean fly *Agromyza phaseoli,* and of "little leaf" virus—probably allied to "big bud" of tomato—and difficulties in achieving effective nodulation all serve to complicate the situation. Nevertheless good stands of *Desmodium* species, *Indigofera endecaphylla, Phaseolus lathyroides,* and *Stylosanthes bojeri* have been achieved. White clover, *Trifolium repens,* has persisted well and given valuable winter and spring production when properly nodulated and adequately fertilized.

(iii) *Plant Nutrition.*—Field and pot culture studies are directed towards ascertaining nutrient deficiencies using legumes as indicator species. *T. repens* is used as the indicator in the winter aspect, *Phaseolus lathyroides* and *Desmodium uncinatum* in the summer aspect.

Selected soils on the experiment sites at Beerwah, Elimbah, and Glasshouse were examined by the Division of Soils (*see* Chapter II.). The soils are extremely low in nitrogen, phosphorus, and bases. They are also extremely low in base exchange capacity and are poorly buffered. Their pH values are from 5.2 to 5.4.

Virtually no growth of legumes can be obtained either in pots or in field plots unless phosphorus is applied. Calcium, potassium, copper, zinc, and molybdenum are also deficient and progressive yield responses to application of these elements are obtained. A similar study of six soils from the Maryborough-Boonooroo plain gives parallel results. These soils also show extreme deficiency of phosphorus. The severity of the deficiencies is greater with increasing depauperization of the endemic flora—from the eucalypt forest of the better-drained ridges down through to the extremely depauperate heaths of the waterlogged plains.

There is but scanty knowledge of the normal chemical composition of the subtropical grasses and legumes, and no characterization of their foliar symptoms when one or more nutrients are deficient. *Phaseolus lathyroides, Desmodium uncinatum, Indigofera endecaphylla, Paspalum dilatatum,* and *Paspalum scrobiculatum* are being grown in water culture to ascertain the contents of the essential elements in the healthy plant as well as in plants grown in nutrient solutions critically low in these elements. A similar study of *T. repens* is also being made, partly as a check in technique and partly to extend information on this species to include trace element contents.

(*b*) *Spear Grass* (Heteropogon contortus) *Region.*—This region of about 43,000,000 acres includes the subcoastal foothills and ranges of the Mary, Burnett, Fitzroy, and Burdekin River watersheds. *H. contortus* is characteristically present to a greater or lesser extent on the whole of this country and forms 75-90 per cent. of the pasture on about one-third of the land. About 1,300,000 beef cattle are grazed in the area, together with 476,000 dairy cattle, the latter on the more favorable areas. The soils are of low fertility, the rainfall is generally over 30 inches per year, and there is little or no use of crops or improved pastures except on the more favorable sites, where dairying is just practicable.

The earlier studies on the natural pastures of this region have now been terminated. These included: yield, botanical composition, and chemical composition of the spear grass pastures, the effects of burning off, and the problem of regeneration of the eucalypt forest. It is clear that the level of productivity from these natural pastures is far too low for any appreciable economic improvement to be based on them. The use of fire is the direct result of the low quality of the natural pastures when mature and dried off during the winter. In turn the burning of the pastures is a major factor in the dominance of *Heteropogon contortus* in the zone. Regeneration of eucalypts is regarded as an expression of the lack of density and vigour of the natural pastures, and killing the regenerating stands does not eliminate the fundamental cause of this serious economic problem in the beef cattle industry.

Experiments are in progress to devise pastures which will simultaneously overcome the low productivity, the necessity for burning, and the regeneration of the eucalypts. They include testing a range of species and mixtures under more favorable nutrient supply. The main experiments are being done at Rodd's Bay station, 30 miles south of Gladstone, with less detailed studies at Calliope station, 30 miles inland from Gladstone.

Phaseolus lathyroides and *Medicago sativa* have been used as test plants to determine nutrient deficiencies on the Rodd's Bay soils, using a combination of field and pot culture tests. Phosphorus is the major deficiency; small but significant responses have been obtained in the field to potassium and molybdenum. In pot cultures small increases were also given by calcium and sulphur. Field trials at Rodd's Bay include test rows of selected pasture and browse species and small plot studies of grass-legume mixtures, all under intermittent grazing.

An area of 250 acres of spear grass pasture was oversown with Townsville lucerne (*Stylosanthes sundaica*) in December, 1949, and fertilized with 1 cwt./acre of superphosphate at seeding and again in December, 1951. The legume has now built up to a reasonable level and during 1953 a definite improvement in the stock was apparent. A comparison of carrying capacity and liveweight of cattle grazing on the spear grass alone and spear grass plus Townsville lucerne is being commenced.

(*c*) *Sown Pastures on Black Soils* (*Cooper Laboratory, Lawes*).—(i) *Lucerne and* Paspalum scrobiculatum.—High yields of nutritious fodder are given by the grass *P. scrobiculatum*, but its relatively low protein content does not provide the lactating ewe or the lamb with enough protein for maximum growth of the lamb. Supplemented with lucerne (*Medicago sativa*) a high-producing well-balanced ration can be achieved. A mixture of the two species, either in inter-cultivated rows or in swards, results in lower total production of nutrients for sheep and in increased weed growth as compared with separate stands of the two species.

The period of growth of lucerne closely reflects the incidence of seasonal rainfall, whereas with *P. scrobiculatum* the period of growth is primarily determined by temperature and only the yield is a reflection of the rainfall. The grass makes its main growth during the higher temperatures of late spring and summer; the lucerne, however, will make substantial growth during the winter period provided that soil moisture is present. Winter production in lucerne can therefore be increased by row cultivation, because there is a reduction in the use of water by the lucerne rows in the summer months, on account of the reduction in gross yield at this period when soil moisture and temperature are both favorable.

An experiment was commenced to measure production from three pastures, viz. (i) a mixture of *P. scrobiculatum* and *M. sativa* in swards; (ii) separate areas of *P. scrobiculatum* in swards and *M. sativa* in rows; (iii) a mixture of *P. scrobiculatum* and *Phaseolus lathyroides* in swards and *M. sativa* in rows.

(ii) *Digestibility and Yield of Selected Subtropical Pasture Species.*—A study of the yield of digestible nutrients, using sheep in pens and in grazed plots, from the most promising pasture grasses and legumes was commenced. Attention is being devoted to the use of "tracer" techniques. *Paspalum scrobiculatum, Panicum maximum* var. *trichoglume,* and *Urochloa pullulans* are being fed.

(*d*) *Plant Biochemistry.*—A research programme on the chemistry of subtropical pasture species was commenced. In conjunction with the studies of digestible nutrients in these species, a programme of lignin analysis was begun. The lignin ratio technique, which elsewhere has been used successfully to estimate digestibility and intake of feed by grazing animals, seemed after modification to be the most promising method.

Preliminary work has been commenced on the study of protein metabolism in selected subtropical pasture species. The effects of potassium deficiency on the free amino acid content of some subtropical legume species are being studied. The findings are consistent with Rothamsted studies on the nitrogenous metabolism of barley where a diamine, putrescine, was shown to accumulate in relatively high concentrations. The work is being extended to the possible effects of deficiencies of essential elements other than potassium on biochemical processes within the plants. Techniques are being designed to make semi-quantitative measurement of organic acids, α-keto-acids, and amines. Chromatographic techniques for estimating the cation and anion contents of the plants are also being sought. Determination of the function of certain elements is the long-term objective, but the immediate aim is to define the nutritional requirements of subtropical species.

Chemical analyses for nitrogen, crude fibre, calcium, phosphorus, potassium, copper, zinc, and molybdenum are being made as a service for colleagues concerned in field and pot culture studies. Tests for free and combined hydrocyanic acid and alkaloids were done on recently introduced plants.

(*e*) *Legume Bacteriology.*—A study of the problems of symbiotic relationships of subtropical and tropical legumes has been commenced and field collections of *Rhizobium* from native and cultivated leguminous species have been made.

Techniques were studied for testing *Rhizobium* strains for effectiveness, particularly as cowpea is the standard test host for most of the strains required in a subtropical area. The standard United States Department of Agriculture technique using a dolomite-sand mixture irrigated with acid culture solution appears promising.

Work was commenced on the assessment of the nodulation habits and effectiveness of *Stylosanthes* spp., particularly *S. sundaica* and *S. gracilis,* in order to form an opinion of their potential worth as nitrogen accumulators.

(*f*) *Plant Breeding.*—Work was commenced on the genetical aspects of selected pasture legumes and grasses relevant to their improvement and adaptation to coastal and subcoastal Queensland. The species selected include those found to be promising by the agrostological work of the Brisbane Laboratory, and related species with desirable characters. The legumes studied include lucerne (*Medicago sativa*) and white clover (*Trifolium repens*) and others in the following genera: *Indigofera, Phaseolus, Desmodium, Leucaena,* and *Stylosanthes.* Grasses studied are mainly of the genera *Paspalum* and *Panicum,* and in these apomixis prevents the development of variation by ordinary breeding methods. Special techniques are being investigated to overcome this barrier. The mode of pollination in *Phaseolus* spp., *Stylosanthes gracilis, Leucaena glauca, Desmodium* spp., and *Indigofera* spp. is being examined. The *Phaseolus* spp. and *Stylosanthes gracilis* are autogamous, while *L. glauca* is allogamous.

Interspecific crosses have been attempted between the annual *P. lathyroides* and the perennial *P. bracteatus,* and between appropriate species within the genus *Desmodium.*

Resistance to a yellow virus allied to big bud of tomato, to the nematode *Meloidagynae incognita,* and to the bean fly *Agromyza phaseolii* is being sought in the subtropical legumes.

22. BIOPHYSICAL RESEARCH.

(University of Tasmania.)

(i) An automatic apparatus for obtaining continuous records of electric potentials at a number of points in the neighbourhood of growing roots has now been constructed and used in test experiments. These records have given interesting preliminary information with regard to unexpected short-period electric oscillations which take place when the growing root is subjected to certain stimuli.

A great deal of pioneering work had to be done to get this automatic apparatus to fulfil the rather stringent requirements imposed on it. It is believed that the instrument as now working is in advance of anything yet recorded for the purpose for which it is designed.

(ii) A study is being conducted of electric potential and potential changes when fine probes are inserted in a *Nitella* cell. The object is to study the electric processes associated with movement of ions across the boundaries within the cell, and in particular the roles played by the plasmalemma and the tonoplast.

IV. IRRIGATION.

1. GENERAL.

The production of crops under irrigation requires specialized techniques, and the continued application of water to the soil can result in problems not encountered in dry land agriculture. The deterioration of land under irrigation is a world problem of great magnitude.

For the study of ways in which irrigated land can be made to keep its fertility, and waterlogged land can be reclaimed, the Organization has two Irrigation Research Stations: the Commonwealth Research Station (Murray Irrigation Areas) at Merbein, Victoria, on the Murray River, and the Irrigation Research Station (Murrumbidgee Irrigation Areas) at Griffith, New South Wales. Both are situated in the midst of important irrigation settlements and keep in close touch with the settlers. The work of these two stations is reported in this Chapter.

Research into soils and their behaviour under irrigation has been carried out at both Merbein and Griffith in close co-operation with the Division of Soils (*see* Chapter II.).

Studies on irrigated pastures are carried out a Deniliquin, New South Wales, by the Division of Plant Industry (*see* Chapter III., Section 19), and other investigations of irrigation techniques for northern tropical areas are carried out by the Land Research and Regional Survey Section at the Kimberley Research Station near Wyndham, Western Australia (*see* Chapter XI., Section 3).

2. COMMONWEALTH RESEARCH STATION (MURRAY IRRIGATION AREAS), MERBEIN, VICTORIA.

The Commonwealth Research Station, Merbein, is concerned with problems of production under irrigation along some 300 miles of the Murray valley, centred on the Mildura district. The crops grown include vine and tree fruits, citrus, vegetables, pastures, and fodder crops. Irrigation water is pumped in some districts but gravitated in others, and most of the horticultural areas have been tile drained.

An important part of the Station's work deals with the reclamation of deteriorated horticultural lands which have not responded to tile drainage. Water usage in vineyards is being examined to assess the requirements of drainage systems.

Of the horticultural crops, vines for dried fruit are the most important. It is pleasing to record that the yield potential for sultanas as indicated by the May, 1953, bud examination and by later bunch counts was fully realized in 1954, and that there was a minimum of loss from disease and from harvest damage. Currant yields were low, however, and little in the way of conclusive results emerged from comparisons between hormone sprays and cincturing. Investigation of some of the components of sultana yield is being continued, and of manurial and cultural practices.

Further investigations of flowering and fruiting in citrus have been made, and the programme of tomato breeding for field and glass-house has been maintained with the collaboration of the Division of Plant Industry.

(*a*) *Irrigation, Soil Preservation, and Reclamation.*—A systematic investigation of drainage conditions at Renmark, South Australia, has been continued from earlier years. Many of the soils in this settlement are very heavy in the upper horizons, but are underlain by beds of sand starting at 3-50 ft. from the surface. With irrigation, these aquifers have filled with saline waters, and deterioration of land and vines has followed.

Tile drainage as practised in other areas of irrigated viticulture in the Murray valley has been tried and found unsatisfactory in these heavy Renmark soils. For some years experiments have been in progress to ascertain the effects of pumping this saline groundwater from the aquifers in order to encourage leaching of salt and soil improvement in the top 4 feet or so actually supporting the vines.

Pumping from four bores took place during the year, but as in other years there has been difficulty in getting continuous pumping. It is possible that this has been a factor in the lack of definite response of heavy soils to this method of draining.

The number of piezometers installed has been increased and ground-water observations have continued. Magnitudes of the various gains and losses of underground water have been calculated, and while exact balance has not been achieved the information obtained allows preliminary calculations to be made for predicting the behaviour of possible future drainage systems.

(*b*) *Land Use.*—Soil surveys are still being made by this Station, primarily to answer local questions on land use. The soil survey begun last year of 1,300 acres of land at Nangiloc and Colignan, Victoria, has now been completed; this area is a recent private development of land near the Murray, with citrus and vegetables under sprinkler irrigation as the main crops.

A further 330 acres has been added to the soil map that the Station supplied in 1950 for a proposed irrigation area, largely for horticulture, at Buronga, New South Wales.

Reports have also been made on two areas of river flats totalling 1200 acres in connexion with proposals by pastoral companies for establishment of irrigated pastures.

Another aspect of land-use studies is the renovation of land on which vine growing had been abandoned at Woorinen. Nearly six years ago two such areas were selected there for the growing of pastures and lucerne, so that the value of this alternative land use could be seen, and the value of such growth in fitting the ground for a return to horticulture determined. Establishment of pasture and lucerne was satisfactory although neither has been very productive, and both areas will probably be planted to fruit trees next spring.

Close association has continued with the activities of the Wakool Land-Use Committee, which has embarked on an extended programme. Analyses have continued at Merbein of the large number of soil samples taken from the Committee's plots after seven years' irrigation of winter and summer pastures. An exploration is being made of factors which might have contributed to the invasion of Wimmera ryegrass and subterranean clover pastures by bastard barley grass. The indications are that soil salinity is not the determining factor.

(*c*) *Horticulture.*—The analysis of crop development in the sultana has been continued, with bud examination in May, 1953, indicating an average crop potential, 45 per cent. of the buds being fruitful. Bud burst was seven-ten days later than in the last few seasons, but the May figures for fruitfulness were confirmed by the October examination. Good weather and a disease-free growing period gave a good yield. The district sampling by the Station showed an average size of bunch and percentage of sugar higher than for last season.

For May, 1954, the bud examination figures are the third highest (62) for percentage fruitfulness and the second highest for primordium size for the nine-year period for which comparable figures are available.

A comparison of May and October fruitfulness over the last two seasons of vines in the recently established soldier settlement at Robinvale with that of the older vines of the Sunraysia district shows no difference between the districts.

A sultana cincturing trial, to determine whether cincturing could increase yield in a season of low fruitfulness, has now had its third harvest but its main object has not been achieved, because the seasons have all been ones of average or good fruitfulness. In accordance with earlier findings, vines cinctured for the third time yielded less green weight of fruit this year, and their growth was much weaker than that on the uncinctured vines. In the pruning trial on sultanas where different numbers of canes had been retained for three years, all canes being of the same length, in the fourth year all vines were pruned to the same number of canes. At harvest those vines which previously had the highest number of canes gave the least crop.

With currants, unfavorable weather and widespread infestations of bunch mite during the past season severely reduced many crops and rendered the yield comparisons inconclusive from most of the trials comparing hormone sprays and cincturing. From the one property where definite results were obtained, vines in their fourth year of spraying with 2,4-D gave a 25 per cent. greater yield than cinctured vines, while vines in their second year of spraying yielded somewhat better with 2,4-D than with *p*-chlorophenoxyacetic acid (P.C.P.A.). On two other blocks there appeared to be no difference between the two spray materials, while on a further two blocks P.C.P.A. seemed to be somewhat better.

There are three trials in the mid-Murray vine-growing districts directed towards the improvement of vine growth on heavy soils. Two at Woorinen include gypsum and sulphur dressings, and one of these has a "no cultivation" treatment, the weeds being controlled by oil spray. These trials, now in their fifth year, are still inconclusive.

"No cultivation" is also under trial at the Station, both as oil spray control of weeds, and as a permanent cover of white clover. Sultana vines on the oil spray treatment are behaving and yielding practically the same as those under normal cultivation. The white clover, however, causes some moisture stress towards the end of every inter-irrigation period under present irrigation spacing, and although clover treatments had more bunches per vine and a higher percentage of fruitful shoots than normal cultivation, their final yield was much less, owing to their much smaller berries.

A survey of vine health at Woorinen was made again in December. The finding for the two preceding years on the same sites was confirmed—a significant correlation between vine health rating and leaf chloride —and the improvement in health then observed had been continued. However, the fact that until this last survey there was no significant decrease in chloride indicates the importance of some factor other than chloride, and from the preliminary examination mentioned in the last report, moisture stress during the irrigation season was suspected. Accordingly measurements of shoot length were made on selected sites from mid-October to January, and of bunch volume from mid-January to harvest, but the season was an unusual one. Until early November cold weather seemed to limit growth, and a relatively mild summer from mid-January on caused only a fifth of the sites to show any halts in bunch growth.

Use of vine measurements to indicate moisture stress was examined in more detail on the above-mentioned cultural methods trial at the Station. Shoot length was useful till mid-December and bunch volume was quite satisfactory after early January, but leaves and tendrils could not be used.

For tick beans, which are still the most usual green manure crop in these districts, the need for annual dressings of superphosphate for maximum growth on Coomealla sandy loam has again been confirmed. An extension of the trial to a heavier soil was inconclusive because of moisture shortage.

A further trial has been made of various insecticides for the control of mealy bugs on vines, and has shown summer sprays of DDT, "Hexone", or "E605" to reduce the number of mealy bugs on bunches at harvest time.

Following previous work by this Station on growth of oranges, weekly measurements of the circumference of small mature Valencia oranges on a grove at Merbein between November, 1953, and February, 1954, showed that the oranges made no appreciable growth during this period. It had been believed in some quarters that late picking of small fruit might give increased pack sizes. Fruit quality was not substantially altered by late picking.

Investigations of the effects of defoliation of flowering shoots on the flowering and fruiting of orange trees were commenced in late 1953. Defoliation was carried out about one month before blossoming. Results are not yet conclusive.

(*d*) *Plant Nutrients.*—The most important nutrient for the vine in this region appears to be nitrogen, and the Station is investigating the nitrogen status of vine and soil under various treatments. It has been said that nitrogen is usually the only fertilizer element applied to which sultana vines respond, but this response does not occur on all soils nor in every year. On the comprehensive fertilizer trial on the medium-textured soil of the Station, the response to an annual dressing of 4 cwt./acre of ammonium sulphate had been consistent until 1953, when it was apparently masked by an attack of black spot, a larger experimental error also affecting this year's harvest. However, a trial designed to test time of nitrogen application on the same soil type also showed no response this year to 3 cwt./acre of ammonium sulphate, in single or in split dressings; and a long-standing fertilizer trial on a sandy soil at Red Cliffs, in which the ammonium sulphate dressing is also 3 cwt./acre, was equally disappointing.

This position is being investigated by two trials of the rate of application of nitrogen, in which one treatment involves the deliberate depletion of nitrogen. In the second year this has caused a decrease in yield at one site on sandy soil at Merbein, but not on the other, at the Station.

Nitrogen has also been applied as a urea spray in another experiment begun last spring, and yields tend to show an increase with increasing urea application. The maximum application was equivalent to about 1½ cwt./acre of ammonium sulphate, sprayed on twice a week up to the end of December.

The relation between soil nitrates, end leaf nitrogen, and various levels of applied nitrogen has been investigated on the two rate-of-application-of-nitrogen trials already mentioned. On Coomealla loam and sandy loam, sulphate of ammonia or green manure gave higher leaf nitrogen, but the level of leaf nitrogen decreased as the season progressed. On Murray sand, differences were less and values were lower. For soil nitrate in the first six inches of soil, significant effects from sulphate of ammonia and green manure were found well into the summer.

(*e*) *Fruit Processing.*—This is reported in Chapter XIII., Section 14.

(*f*) *Vegetables.*—The trial of "Krilium" for soil conditioning in glass-houses gave inconclusive results on Curlwaa loam last year, and this year a further trial has been started on a heavier soil type.

Work on development of tomato varieties resistant to fusarium wilt was continued at Red Cliffs. Further selections were made on several advanced hybrids and some promising lines have been evolved, particularly for bush type, yield, and fruit quality. It is considered that these hybrids are now sufficiently fixed to include in comparative field trials.

Work on hybrids resistant to root-knot nematode has also been continued. One of the best resistant parents is the variety of H.E.S. 4242, the seed of which was imported from America for the purpose, and it has been used as one parent in most of the recent crosses.

Several first back-cross generation hybrids were grown at Canberra and selections made for agronomic types; they were allowed to self pollinate and their seed was then planted in infected areas at Red Cliffs for further selection.

During the 1953-54 season, 55 nematode-resistant hybrids were selected for future work. To determine their resistance, roots of all plants were examined individually and a rating of 0 to 5 given for severity of infection. Good progress is being made towards obtaining a highly resistant tomato with desirable agronomic qualities.

A trial of the effects of methods of farm management on the root-knot nematode population of soil at Red Cliffs is still in progress. Host relationship studies are being made to give positive identification of the principal nematode present, which is morphologically similar to *Meloidogyne incognita* (Chitwood). Nematodes of several other genera are commonly associated with the root-knot nematode in galls on tomato roots. Improved nematode resistance in tomato lines recently selected has resulted in an appreciable decrease in nematode population in "resistant" plots during the past season. The barley cover crop used in one treatment is susceptible to *M. incognita,* though infection is apparently slight or absent. This may be due to low temperatures. The vigour of susceptible tomatoes planted in the field or in samples from control plots is greatly reduced by severe nematode attacks.

3. IRRIGATION RESEARCH STATION (MURRUMBIDGEE IRRIGATION AREAS) GRIFFITH, NEW SOUTH WALES.

The increasing age of the Murrumbidgee Irrigation Areas, which comprise two-thirds of the irrigation area of the State of New South Wales, has brought to a head problems associated with the application of irrigation water to the soil.

Every district has experienced to some degree the threat of waterlogging, while the incidence of salting has been so heavy in some localities as to provoke grave fears for their ability to maintain their productivity.

The work of the Research Station at Griffith has been designed to lay the basis for an effective counter to waterlogging and salting and to develop more efficient techniques in the use of irrigation water.

Investigations already undertaken have been used to launch a large scheme for underground drainage designed to stabilize production on problem properties, and this is being undertaken by a combination of government agencies and co-operating farmers' organizations.

Research now in progress is designed to increase the effectiveness of the scheme, to enable sounder approaches to be made to irrigation farming generally, and to discover means of arresting adverse citrus-growing phenomena which are associated with plant nutrition and other factors and which are to-day posing serious problems in terms of market quality.

(*a*) *Irrigation.*—Studies being undertaken at the present time are making it possible to determine several weeks in advance when water will have to be applied to the farms of the irrigation areas. This means that it is possible to indicate when the non-irrigation season should be terminated in spring and water released from Burrinjuck Dam.

This permits the maximum time for essential maintenance work on irrigation structures, while eliminating the risk which existed in the past of crops being stricken by drought in the non-irrigation season. The work is also of importance during the irrigation season in determining irrigation schedules.

One method being employed to study the effect of weather elements and soil moisture on the rate of withdrawal of water from the soil by plants under field conditions is to use tanks sunk into the ground. The weight of the tanks can be readily measured to determine the amount of water loss, and continuous records are obtained of the incoming radiation, wind, and vapour pressure.

Data are also obtained on a district basis by following the moisture content of the soil by means of direct sampling from a number of selected orange groves distributed over the irrigation areas.

It is in this way that the relation between the weather and soil moisture on the one hand and the rate of withdrawal of soil moisture on the other is determined.

(*b*) *Drainage.*—Farm-size tests have been in progress of the feasibility under irrigation area conditions of reclaiming salted land by tile drainage. Of the two experiments on selected salted farms, one has now been completed and changes in the soil salt, water-table, and health of plantings have been noted.

In the completed trial, reclamation from the salted conditions was completed within two years, with most of the improvement occurring in the first year.

In the trial still being continued reclamation has been slower, owing, it is believed, to very light applications of irrigation water by the farmer, which have been insufficient to leach down the salt.

An examination of the data gathered in the trials indicates that salted land on the Murrumbidgee Irrigation Areas can be reclaimed by tile drainage and, as a result, a comprehensive scheme of tile drained orchards has been initiated to overcome the hazards of waterlogging and salting.

The depths and spacing of the tile drains adopted for the various soil types is based on studies carried out at the Station in which short trenches were used to determine the "drainability" of the soils.

(*c*) *Soil Salt.*—A survey of the incidence of soil salt and modes of development of salting is being made in a selected portion of the horticultural area. Farmers are being visited and notes on past and present cultural methods are being made. Soil and leaf samples are collected for analysis. Data already examined indicate that liability to salting is associated with the geomorphology of the locality. Salting occurs in sand-filled depressions of the heavy plain country. Salt damage on the heavier soil at the bottom of the rather steeper slopes is greater than on the somewhat higher lighter soil. The composition of the salt is also related to the geomorphology. Differences are noted in the liability of different kinds of crops to salting. This survey is preliminary to more detailed work on the effect of geomorphology on the incidence of salting.

(*d*) *Horticulture.*—The factorial field experiment with oranges, embracing four irrigation, four cultural, and four nitrogen treatments, and four stock-scion combinations—256 different treatments in all—has continued.

The weeds-mown (grass sod) treatment has continued to depress tree growth and yield. The health of the trees on the weeds-mown, no nitrogen plots is very poor.

The superiority of the bare soil treatment over the two summer clean cultivation treatments has decreased. In the attributes of size (spread, height, and butt circumference) there is no significant difference between these cultural treatments.

The yield of the bare soil treatment in the last two years (weight and number of fruits per tree) has been slightly lower than those of the two summer clean cultivation treatments.

It has been found that manganese deficiency appearing in this field is associated with the soil reaction. Dressings of ammonium sulphate which reduce the pH also reduce the incidence of manganese deficiency, while bringing up limestone in the subsoil to the surface increases the pH and the incidence of manganese deficiency. Trees on tilled plots which received dressings of superphosphate contain more leaf manganese than trees on plots not tilled which did not receive superphosphate. When the leaf manganese falls to 20 p.p.m., 50 per cent. of the trees show visual manganese deficiency symptoms. Other symptoms of malnutrition are showing up, mainly in the weeds-mown plot, and to a lesser degree in the oil spray treatment. These symptoms are suspected to be of phosphorus deficiency.

In connexion with these developments a nutritional investigation, including analyses for nitrogen, phosphorus, and if time allows, other elements, has begun.

(*e*) *Plant Physiology*—(i) *Plant Water Relations.*—If irrigation is to be conducted on the soundest lines, it is important to understand how correct use of water is related to the development of the plant. To achieve such an understanding it is necessary to assess first the response by the plant to a brief change in the water régime. The response to change has been determined for the tomato and for flax for a brief period of wilting during otherwise normal soil moisture relationships. Two levels of water shortage were established and in the most severe the soil moisture at no time dropped below the permanent wilting percentage.

In the tomato, the response of the individual laminae and petioles and of the other plant parts was considered in relation to that of the plant as a whole. It was found that a higher stem weight ratio and a lower lamina weight ratio were developed during wilting, and that growth rates were depressed. Upon rewatering, the resumption of active growth was rapid and the change in weight ratios was reversed. The changes in growth rates were seen to result from the response to treatment of the younger laminae and, in all probability, of the younger portions of the more mature laminae. The changes in weight ratio were the result of modifications to the normal pattern of translocation between plant parts.

Chemical analyses for nitrogen, phosphorus, and protein nitrogen showed that very little nutrient was taken into the plant during the water shortage, but that resumption of active uptake occurred upon rewatering. This uptake was most marked in the younger laminae and probably in the younger tissues of the older laminae.

It was evident that the response to treatment occurred at some stage before the development of even the more moderate water shortage and that it would be important to assess the degree of water stress when the growth of the plants was first impaired. It was also evident that the younger tissues of the plant were the principal centres of the response noted.

(ii) *Citrus Physiology.*—The physiological studies of growth and nutrition in fruit trees are rendered more than ordinarily difficult by the size and complexity of the experimental plant, but studies of leaf composition can be useful in picking up nutrient deficiencies which might not affect fruit yield for a number of years. They can also be expected to help in the interpretation of the effects of cultural and irrigation treatments such as those imposed on the experimental citrus grove at this Station (Farm 466). Accordingly, leaf samples were taken at 6-monthly intervals and determinations made of leaf area, fresh and dry weight, nitrogen, and phosphorus. The samples were taken in such a way that comparisons will be valid from occasion to occasion as well as between treatments. Among other things, the results show that phosphorus deficiency is appearing in certain treatment combinations.

V. ANIMAL HEALTH AND PRODUCTION.

1. General.

Live-stock have a fundamental role in the primary industries of the Commonwealth and research into problems of animal health and animal husbandry forms an important phase of the Organization's activities.

This work is centred in the Division of Animal Health and Production with head-quarters in Melbourne, and is aimed at increasing the general productivity of the animal industries by investigation of problems concerned with animal health, genetics, breeding, nutrition, and physiology with particular reference to reproduction.

The Division's major activities and the results obtained are reported in this Chapter and in Chapters VII. and VIII. The work of the Division of Biochemistry and General Nutrition on the nutritional maladies of animals is reported in Chapter VI.

Section 12 of this Chapter sets out the investigations carried out by the Animal Genetics Section, other than those on sheep and cattle which are included in Chapter VII., Section 14, and Chapter VIII., Section 7, respectively.

Division of Animal Health and Production.—There was little change in emphasis in the work undertaken during the year but notable advances were made in providing facilities for the investigational programme. The staff of the Sheep Biology Laboratory has been concentrated at Prospect, New South Wales, where considerable progress has been made in the provision of laboratory and ancillary facilities. In addition, the National Cattle Breeding Station at "Belmont", near Rockhampton, Queensland, has been developed with fencing and watering facilities, the station has been stocked, and an experimental programme is under way. Plans are in hand for setting up a small laboratory in Rockhampton for work on the physiology of dairy cattle in a tropical environment.

Certain changes in senior staff have occurred. Dr. J. M. Rendel has become an Assistant Chief of Division, to assist in the further development of the animal breeding programmes. Dr. R. B. Kelley, O.B.E., Assistant Chief and officer in charge of the F. D. McMaster Field Station, has retired but is continuing as consultant in the work concerned with the production of types of cattle suitable for tropical areas. Mr. R. H. Hayman has succeeded Dr. Kelley as officer in charge of the Field Station. The officer in charge of the Wool Biology Section, Mr. H. B. Carter, has resigned and has been succeeded by Mr. P. G. Schinckel at Prospect.

A conference was held at Young, New South Wales, to discuss problems associated with footrot in sheep. The conference was attended by representatives of the Division and by veterinary officers of the Departments of Agriculture and dealt with problems of differential diagnosis, treatment, and practical control.

Co-operative research with other Divisions of the Organization, with Departments of Agriculture, and with the universities has continued. It is desired to express appreciation of this co-operation and also of the financial and other assistance received during the year from the wool industry, the Australian Meat Board, the Australian Dairy Produce Board, and the Commonwealth Bank.

2. ANIMAL HEALTH RESEARCH LABORATORY, MELBOURNE.

(Division of Animal Health and Production.)

This laboratory houses the administrative headquarters of the Division as well as research staff concerned with investigations in the fields of animal physiology, general and chemical pathology, certain infectious diseases, and microbiological chemistry. The main investigations in progress are:

Pleuropneumonia of cattle (*see* Chapter VIII., Section 2 (*a*)); mastitis in dairy cattle (*see* Chapter VIII., Section 2 (*b*)); haematuria vesicalis of cattle (*see* Chapter VIII., Section 2 (*d*)); brucellosis of cattle (*see* Chapter VIII., Section 2 (*c*)); physiology of milk secretion (*see* Chapter VIII., Section 5 (*b*)); toxicity of large rations of wheat (*see* Chapter VII., Section 11); infertility and physiology of reproduction in sheep (*see* Chapter VII., Section 12); sheath rot of wethers (*see* Chapter VII., Section 17 (*c*)); "toxaemic jaundice" of sheep (*see* Chapter VII., Section 17 (*b*)).

3. McMASTER ANIMAL HEALTH LABORATORY, SYDNEY.

(Division of Animal Health and Production.)

The major investigations undertaken at this Laboratory include studies on internal and external parasites of sheep (*see* Chapter VII., Sections 18 and 19); problems concerned with drought feeding of sheep (*see* Chapter VII., Section 10); feeding of beef cattle (*see* Chapter VIII., Section 6); fundamental studies on physiology of reproduction (*see* Chapter VII., Section 12); biochemical studies; and the investigation of certain infectious diseases. During the year the work on carbohydrate metabolism and pregnancy toxaemia was transferred to the Sheep Biology Laboratory at Prospect. Efforts were made to find a more effective cure for footrot in sheep. The section which undertakes fundamental studies in skin tissue culture is also housed at the McMaster Laboratory.

The Division of Mathematical Statistics works closely with the McMaster Laboratory and the help of the officers of this Division in the planning of experiments and the interpretation of results is indispensible.

4. VETERINARY PARASITOLOGY LABORATORY. YEERONGPILLY, QUEENSLAND.

(Division of Animal Health and Production.)

This Laboratory was established in 1948 to undertake investigations into parasites affecting live-stock, particularly cattle. The Laboratory also provides accommodation and facilities for officers of the Division of Entomology who are engaged in investigations into the control of the cattle tick (*Boophilus microplus*). Facilities for field work are provided at Amberley field station, near Ipswich.

Close co-operation with the State Department of Agriculture and Stock is maintained and is assisted by the Joint Veterinary Parasitology Committee.

Investigations in progress by officers of the Division of Animal Health and Production include the following studies:—

(*a*) *Liver Fluke.*—Studies on the molluscan intermediate host of *Fasciola hepatica* have shown that *Simlimnea subaquatilis,* which is the sole vector on the mainland, is also present in Tasmania.

The areas treated wtih sodium and copper pentachlorophenates late in 1952-53 were inspected six months after treatment, when it was found that the populations in the areas treated with the sodium salt and the lower concentrations of the copper salt had attained pretreatment intensity. The area treated with 4 lb. copper pentachlorophenate per acre as a spray, however, gave more promising results, for at the time of inspection repopulation was just commencing.

(*b*) Haemonchus contortus *of Cattle and Sheep.*—It was concluded from observations based mainly on the morphology of the infective larvae, and on the type of cuticular vulval process dominant in adult females in natural populations in sheep and cattle, that the so-called ovine and bovine "strains" of *Haemonchus contortus* showed specific distinctness. Further work involving cytological examinations has been undertaken and studies have been made of the chromosomes in aceto-orcein squashes of the gonads.

(*c*) *Tick Toxonomy.*—Assistance in the identification of tick specimens has again been given to various institutions throughout Australia.

(*d*) *Host Reactions to Tick Infestation.*—Studies will be commenced in the near future to compare the reactions of British breeds of cattle and Zebu cattle to infestation with the tick *Boophilus microplus*. Reference to some preliminary work on this problem at Yeerongpilly was made in last year's Report.

(*e*) *Tick Toxins.*—Work at Yeerongpilly on distilled-water extracts of the eggs of *Boophilus microplus* has shown that the three major components exhibit the characteristic behavious of globulins. The name "ixovoglobulin" is proposed for proteins from this source, and subdivision into α, β, and γ components is suggested on the basis of their different mobilities in an electric field. Separation of a relatively pure ixovoglobulin was accomplished by ammonium sulphate fractionation. This fraction was toxic to guinea-pigs when injected subcutaneously. Separation of the β and γ fraction was obtained by aqueous extraction of an alcohol precipitate of the proteins. This fraction also killed guinea-pigs, but appeared to have a slightly lower toxicity than the α fraction.

Other major investigations in progress are: Epidemiology of parasitic gastro-enteritis of cattle (*see* Chapter VIII., Section 3 (*a*)); faecal examination as a measure of helminth infestation in cattle (*see* Chapter VIII., Section 3 (*b*)); amphistomes of cattle (*see* Chapter VIII., Section 3 (*c*)); worm nodules (*Onchocerca gibsoni*) in cattle (*see* Chapter VIII., Section 3 (*d*)); bionomics of infective larvae of cattle strongyles (*see* Chapter VIII., Section 3 (*e*)); anthelmintics for cattle (*see* Chapter VIII., Section 3 (*f*)); blood minerals in parasitized calves (*see* Chapter VIII., Section 3 (*g*)); protection against body strike in sheep (*see* Chapter VII., Section 20).

5. F. D. McMaster Field Station, Badgery's Creek, New South Wales.

(Division of Animal Health and Production.)

The year has been a dry one, with rainfall 7.5 inches below the average for the eleven-month period to 31st May. Crops of oats, barley, and sorghum failed but millet gave a moderate yield. Pasture growth was satisfactory in the January-March period, but poor during the rest of the year. However, sheep have been maintained in excellent condition by extensive hand feeding. There are now 68 cows in the dairy herd, of which 49 are Zebu cross-breds.

The work with dairy cattle based on Zebu crosses with British breeds is continuing. This study is reported in Chapter VIII., Section 5 (*a*). Other investigations in progress are—Inbred flocks of Australian Merinos (*see* Chapter VII., Section 13 (*a*)); inheritance of component fleece characters (*see* Chapter VII., Section 13 (*b*)); fleece rot (*see* Chapter VII., Section 13 (*c*)); studies on twins (*see* Chapter VII., Section 13 (*d*)); the effect of impaired or imperfect mammary function of the Merino ewe on ability to raise a lamb (*see* Chapter VII., Section 13 (*e*)).

6. Sheep Biology Laboratory, Prospect, New South Wales.

(Division of Animal Health and Production.)

During the year it became possible to transfer the Staff to buildings on the site at Prospect and this has resulted in the closing of establishments at Randle-street, Sydney, and at Villawood, and the transfer of the Endocrinology Section from the Department of Veterinary Physiology, University of Sydney.

Two prefabricated laboratories have been completed and occupied. Construction of the animal examination and climate-controlled building began in January and contracts have been let for the construction of an incinerator and of a rabbit house for the Animal Genetics Section.

The main investigations in progress are concerned with: pregnancy toxaemia in ewes (*see* Chapter VII., Section 9); comparative breed studies (*see* Chapter VII., Section 16 (*a*)); endocrinology of wool growth (*see* Chapter VII., Section 16 (*b*)); experimental histology of skin and hair (*see* Chapter VII., Section 16 (*c*)); studies of skin and fleece development (*see* Chapter VII., Section 16 (*d*)); Physical studies of wool (*see* Chapter VII., Section 16 (*e*)); and routine measurements (*see* Chapter VII., Section 16 (*f*)). The work of the Merino strains trial (*see* Chapter VII., Section 13 (*f*)) is also centred at Prospect.

7. Regional Pastoral Laboratory, Armidale, New South Wales.

(Division of Animal Health and Production.)

Since the acquisition of "Chiswick" in September, 1947, the work of this centre has been concerned with epidemiological and ecological aspects of parasitism, problems of fertility in ewes and survival of new-born lambs, the utilization and management of native and sown pastures and of land units with varying proportions of sown and native pastures, and the effects of grazing management on pastures and on animal production. This work is reported in Chapter VII., Section 21.

The Division of Plant Industry has undertaken an extensive programme based on a detailed ecological survey of the New England region. This programme includes plant introduction studies, problems of plant nutrition, and the development and maintenance of sown pastures. This work is reported in Chapter III., Section 18, and Chapter VII., Section 21.

"Chiswick" is one of the centres for the study of strains of Merino sheep in several environments which is reported in Chapter VII., Section 13 (*f*).

8. National Field Station, "Gilruth Plains", Cunnamulla, Queensland.

(Division of Animal Health and Production.)

The rainfall for the twelve months covered by this Report has been approximately 12½ inches, which is slightly below the average. The early months, July-September, 1953, were characterized by a gradual drying of pastures on both the Mitchell grass (*Astrebla* spp.) and mulga (*Acacia aneura*)-box (*Eucalyptus populifolia*) associations. By the end of September only 1.1 inches had fallen in sixteen weeks. Rains in October and November, over 4 inches in all, were of great assistance to the lambing ewes. Thereafter a summer drought followed until January-February, 1954, when 6.7 inches of rain resulted in excellent grass growth on both the main associations, and good herbage growth on the Mitchell grass association. A further dry period of fourteen weeks followed until the end of May. However, the standing grass growth on the Mitchell grass pastures was well preserved. The less palatable grass species on the mulga-box association were of little value by the end of this period, even mulga Mitchell (*Neurachne mitchelliana*) being almost completely dry. Nevertheless, sheep on the whole have been in good condition throughout the year.

In March, 1954, approximately 4,600 adult sheep and 2,270 lambs were shorn. A high incidence of unsound and tender wool was seen, the cause of which has not been satisfactorily elucidated.

Experimental work during the year was concerned mainly with sheep breeding and genetical studies (*see* Chapter VII., Section 13). In all, approximately 1,600 ewes were mated and lambed under close observation in pens. During the remainder of the year they were under paddock conditions.

Other experimental work included a study of early embryonic mortality. These observations are being repeated during the current mating period (*see* Chapter VII., Section 12 (*b*)).

A study has commenced of the intake of food under paddock conditions by wethers of the strains represented in the strains trial (*see* Chapter VII., Section 13 (*f*)). The work is designed to measure any differences between the strains in efficiency of conversion of food to wool.

Observations on lamb mortality in lambing pens have continued and it is of interest to note that higher losses have occurred among lambs from ewes which are slightly inbred.

9. National Cattle-breeding Station, "Belmont", Rockhampton, Queensland.

(Division of Animal Health and Production.)

The precipitation at "Belmont" for the first six months of this year was 6 inches below the district mean. Rains for the second six months, although about average, were unevenly distributed. Falls which totalled 22 inches in January and February caused serious flooding of the Fitzroy River. In spite of these heavy falls the total rainfall was some 6 inches below the Rockhampton 81-year annual mean of 38.95 inches.

Frequent frosts in the late winter of 1953 caused damage to dry pastures. After 280 points of rain in August it was possible to burn most of the rank feed and a good shoot of nutritious grass followed.

(*a*) *Pastures.*—The total feed available throughout the year was sufficient, but the limitation on usage due to flood and other factors was responsible for periods of nutritional stress.

The good summer rains of 1953 produced excellent growth in all plant associations. The dry winter with heavy frosts caused much of this dry grass to "blacken off". This was more evident on the open country than in timbered areas. The fresh growth after the "burn" in August, carried all stock in good condition into the summer.

Flooding of some four-fifths of the property in February, 1954, limited the pasturage available and destroyed considerable areas of first-class grazing. The effects of flood-water on the pastures appear to have been governed by the length of time areas were inundated, and also by soil type. Survival and ultimate regrowth of pastures were also influenced by the type of flood—whether the waters were fast-flowing forward current or "ponded" waters in back-up areas.

As a result of the flooding there has been a serious loss in the cover of pasture species and, although germination and subsequent growth on the flooded country have been reassuring, it may well take several years of good rainfall before the pastures regain their previous productivity.

(*b*) *Stock.*—Additional cattle required for the experimental programme were acquired early in the year. One bull and 30 cows of the northern-bred–southern-bred Hereford project arrived in August. These were purchased from P. A. Wright and Sons, "Wallamumbi", Armidale, New South Wales. Two pure-bred Africander heifers from King Ranch, Texas, United States of America, also arrived at "Belmont" in August, 1953. Eight young bulls required for oestrus studies were purchased.

Calving in the various groups of cows continued and at present there are some 300 calves and weaners on the property. The total cattle population consists of 24 bulls, 532 breeding cows, and 300 calves and weaners.

(*c*) *Improvements.*—During the year the installation of improvements and facilities required for the experimental programme proceeded. Among these improvements was the erection of 13 miles of cattle fencing to make twelve paddocks, each capable of carrying a single-sire mating group of one bull and 30 cows. Also erected was a set of cattle yards which include a concrete dip, an eight-way drafting unit, calf-branding crush and cradle, weighing crush and scales, speying bail, and a special crush designed for single-animal observations (temperatures and respirations). The provision of permanent water for the various facilities was a major undertaking. It involved the erection of a windmill, 6,000 feet of pipeline, three 5,000-gallon tanks, and fourteen troughs. The improvements installed have been tested under full experimental conditions and found to be adequate.

(*d*) *Genetics.*—For details *see* Chapter VIII., Section 7.

10. Poultry Research Centre, Werribee, Victoria

(Division of Animal Health and Production.)

The Poultry Research Centre houses 3,072 pullets in individual laying cages, 1,920 hens in trapnest sheds and 150 third-year hens in single pens. The number of pedigree chickens hatched and wing-banded annually, from which replacements are selected, is 10,000.

The system of recording and analysing the observations and measurements by means of Hollerith punch cards has been further improved. The system has been described in detail in a *Working Manual on Poultry Records.*

(*a*) *Breeding Systems and Related Projects.*—The population of G pullets had a higher mortality and lower level of egg production than the previous generation of F pullets. The performance of the control flock indicated that this was probably caused by unfavorable environmental factors. Mortality of the G pullets was 23.3 per cent. from housing to 72 weeks; 44.3 per cent. of this was due to leucosis, mostly of the visceral type. Mortality varied significantly between breeding groups and sire families. It was lowest at 12.9 per cent. in the A x L cross-breds and highest at 40 per cent. in the White Leghorns selected for low egg production.

The production data obtained from the different flocks of G pullets, after five to six generations of selection, confirm the tentative conclusions recorded in last year's report. Among the White Leghorn flocks the group bred from progeny-tested parents, without inbreeding, is still leading in egg production, closely followed by the flock bred from high-producing dams and a sire bred from the pullet winning the State Egg Laying Competition. Phenotypic selection on body conformation did not result in any progress. Selection according to the Hagedoorn system reduced mortality, although pullets only were used for breeding, but was not very efficient in raising egg numbers, probably on account of the increasing degree of inbreeding by matings of half-sibs only. The strains of the B.A.I. flock, in which inbreeding is more intense, reached a coefficient of inbreeding of up to 56 per cent., with egg production now at the level of the control flock but not deteriorating further.

The egg production of the Australorps is still below the level of the two best White Leghorn flocks. Crossbreds between the two breeds again surpassed the best parent breed. No difference was found between the different types of crosses. Rotational crossing, now in the sixth generation, continues to give good results. The breeding of three-way crosses will be discontinued as no new information is likely to be gained, and the results obtained from six generations of cross-breeding will be prepared for publication. The programme of single crosses has been modified and will be continued as an investigation on cross-breeding by reciprocal recurrent selection.

A study on the interactions between genotype and environment in determining sexual maturity in the domestic fowl has shown that interactions of non-linear nature do exist in the Werribee flock, but their magnitude is not large enough to invalidate present methods of correction for hatching date. Studies on the measurement of winter pause and on heritability of egg production are in progress.

A study on the effect of intensity of daylight on egg production of fowls kept in cages showed that differences of over 100-ft. candles in light intensities do not affect egg production.

(*b*) *Physiology and Genetics of Reproduction.*—The technique of artificial insemination used at the Poultry Research Centre was further improved by the use of a modified syringe. A mean fertility of 90 per per cent. was achieved from 16,133 eggs set. Semen can now be stored sixteen to twenty hours without seriously impairing fertility. This results from the greater efficiency of the new syringe, which achieves the same fertility with a poorer sample of semen.

Fowl sperm have been labelled with radioactive phosphorus (^{32}P) by incubation *in vitro* with inorganic ^{32}P and then washing free of radioactive plasma. This method was found more effective than intravenous injection of the cockerel with ^{32}P. After insemination with labelled sperm, birds were killed at different intervals of time and it was shown that sperm reached the top of the oviduct within half an hour of insemination. More than 90 per cent. of the semen injected was expelled into the cloaca. Of the sperm retained within the oviduct less than 10 per cent. travelled past the shell gland. The mechanism of sperm transport in the shell gland differs from that in the remaining parts of the oviduct, the latter being more efficient.

Inbreeding was shown to decrease semen volume. Sperm density and percentage of normal sperms were ower in the strains with a low level of egg production than in strains bred for high egg production.

11. MISCELLANEOUS INVESTIGATIONS.

(Division of Animal Health and Production.)

(*a*) *Copper Content of Blood and Liver in Sheep and other Animals in Western Australia.*—Work in his field is continuing. In samples taken in the autumn at Meredith it was found that liver and blood copper levels in sheep were normal and blood molybdenum values were somewhat high. Analyses of pasture amples indicated a low copper status but adequate molybdenum. Liver samples from semi-arid mulga country near Wiluna gave remarkably high values for copper although no reports of copper poisoning had been received from the area.

In studies on the comparative biochemistry of copper, evidence has been obtained of a significant difference n the copper content of the livers of male and female almon collected near Albany.

Laboratory studies in connexion with a survey of the cobalt status of pastures are in progress and work on lover oestrogens is continuing.

(*b*) *Physiological Genetics.*—Micro-organisms are he simplest organisms to use in studies of the biohemical and physiological action of the gene, and most of what is known of the genic control of chemical eactions in the cell has been derived from studies with them. The most useful organisms have been the moulds *Neurospora crassa, Aspergillus nidulans,* and *A. niger* and the bacterium *Escherichia coli.*

Work in this field is proceeding at the Department of Genetics, University of Adelaide. The investigations include studies of the intra-cellular interactions between nuclei of two genetically dissimilar types and the relation of these interactions to the proportion of the two nuclear types present.

Some data of interest on the environmental and genetic control of vegetative spore production by *Neurospora* have been collected. Four genes were involved.

(*c*) *Effects of High Temperature on Pregnancy in Merino Ewes.*—This work is in progress in the Department of Physiology, University of Queensland. High temperature was found to be inimical to satisfactory gestation in Romney Marsh culls and the work has been extended to Merinos, a breed that might be expected to tolerate heat better than the Romney and one which is frequently exposed to high temperatures during pregnancy. Spring mating is practised in north-western Queensland and in other parts of Australia.

(*d*) *The Breeding Season of Merino Ewes in Relation to the Light Environment.*—During recent years it has been demonstrated that the breeds of sheep which have a clearly defined sexual season owe such seasonality to a photoperiodic control. The usual pattern is for ewes to commence breeding in autumn, the onset of ovarian activity being attributable to a period (generally from one to three months, depending on breed) of decreasing daily duration of light. Insofar as the Merino, with its long and rather ill-defined breeding season, is comparable with the mutton breeds, it conforms to their pattern of sexual season reasonably well. However, it tends to be anomalous in certain respects, notably in its capacity, at any rate in certain regions, to commence breeding in summer before the days have started to shorten.

As the Merino has not been studied in light-controlled experiments the present investigation was undertaken to establish whether it is responsive to the light environment and to investigate the unusual features of the seasonal reproductive pattern in this breed. Experiments were commenced at the Department of Physiology, University of Queensland, early in 1954.

(*e*) *Environmental Control of Coat Changes in Cattle.*—The controlling factor responsible for the seasonal coat changes which occur with such precision in most European breeds of cattle in an environment suited to them, has remained unidentified. Environmental temperature has perhaps commonly been assumed as the regulator. However, thermal control, apart from its not having been demonstrated experimentally, fails to explain the difficulty which cattle from high latitudes frequently have in shedding their long, woolly coats in the tropics.

As there is a certain amount of evidence, mainly from other species, that a photoperiodic mechanism is involved, it was decided to undertake experiments at the Department of Physiology, University of Queensland, to test the efficacy of controlled seasonal lighting in regulating coat changes.

The first effect of experimental treatment became apparent in early May, some three months after the experimental animals had been on an increasing plane of daily light. It was noticed that swathes of long hair could be rubbed off the heads and necks of all four calves in the group and it became quite evident that they had commenced to shed. The shedding extended posteriorly during the subsequent weeks, and at present, although in winter, the animals are sleek and glossy, presenting all the appearance of thrifty cattle in summer.

The control calves, on the other hand, have continued to grow a deep, woolly coat, typical of that to be expected in winter. Their hair has remained firmly attached and there has been no sign of shedding.

These visible changes are reflected quantitatively by the weight per unit area of monthly hair clippings.

12. Animal Genetics.

(Animal Genetics Section.)

The Animal Genetics Section was established during 1952 with the co-operation of the University of Sydney; it is located in the Departments of Zoology and Veterinary Physiology and is under the leadership of Dr. J. M. Rendel. The Section aims to investigate the possibilities of applying genetical knowledge to animal breeding, and to introduce University honours students interested in genetics to the techniques and concepts of quantitative inheritance. Two students completed their training with the Section for an honours degree this year. Three students have started their training for the M.Sc. degree. A fourth student taking honours in Physics is working with the Section to determine the rate of mutation of flies exposed to heavy primary particles at high altitudes.

(*a*) *Mouse Breeding.*—The lines of work undertaken in the mouse colony were described in the previous Report. Selection for oestrogen sensitivity continues to be effective. This experiment will now be used to try out methods of testing using a sequential form of test. So far it has shown that progeny testing on from two to three offspring is markedly successful despite the apparent very low heritability of the character. A full analysis has yet to be completed. It has been shown also that the cross of two inbred lines has about half the environmental variance of the inbred lines themselves, and that for assay work the F_1 is much more useful than the pure line. This will apply to all physiological work where uniform biological material is needed. So far no difference can be detected between the lines with high and low response to oestrogen as regards susceptibility to carcinogens.

In the selection experiment designed to increase tibia length in mice a new method of discounting environmental variance has been evolved and will be tried out in future. This method uses Fairfield Smith's model to detect environmental variance in one character from its correlation with a second character.

Further work on hair growth in naked and normal mice has shown that the resemblance between naked and normal hair growth at first observed disappears after the second hair cycle. From then on the normal mouse loses the regularity present in naked mice.

(*b*) *Production of Antibodies and Disease Resistance.*—It has been found that whereas heritability of response to a simple antibody is high, heritability of response to a complex one is low. This appears to be connected with the finding that the response to a high dose of complex antigen is much more variable than response to a low dose; the suggestion is that when the dose is reduced the host reacts to fewer of the haptenes of the complex antigen.

To secure good supplies of complement, strains of guinea-pigs are being selected for high production of complement. During this selection it is hoped to establish something of the heritability of complement production. The possibility of storing complement by freeze drying is being explored.

A rabbit colony of some 300 has now been accumulated and is housed at Glenfield Research Station, where the New South Wales Department of Agriculture has kindly made space available. The colony will be moved to a rabbit house now under construction at Prospect. The technique of breeding from wild females by artificial insemination is now routine. No success has yet
been achieved in collecting semen from wild bucks. T
first generation of rabbits born to recoveries fr
myxomatosis are now coming forward for testing.
far 9 out of 64 have recovered from the KM
strain of myxoma virus, whereas none of the contr
(22) have recovered. It is interesting that all recover
were sired by one buck. Treatment of the virus wi
antiserum has been carried out and has given resu
which are difficult to interpret. It appears that t
virus is at least temporarily transformed by the tre
ment. There are, however, no signs that a stra
resistant to the serum is being selected out.

(*c*) *Genes and Chromosomes.*—It has been esta
lished in collaboration with the Biochemistry Depa
ment, University of Sydney, that the nucleus of t
kangaroo, *Macropus rufus,* contains 3 x 10^{-9} m
nucleic acid per nucleus, an amount typical
eutherian mammals. If nucleic acid content is an in
cation of gene content—which seems highly probab
from work done so far—estimation of nucleic ac
content in marsupials, monotremes, and lower ver
brates may throw light on the mode of evolution of t
mammalia.

(*d*) *Genetics of Sheep.*—The work of the Anim
Genetics Section on the genetics of sheep is reported
Chaper VII., Section 15.

(*e*) *Genetics of Cattle.*—The work of the Anim
Genetics Section on the genetics of cattle is reported
Chapter VIII., Section 7 (*a*).

VI. NUTRITION.

1. General.

The lack of exact knowledge of ruminant physiolo
and the basic importance of the pastoral industries
Australia's economy first prompted fundamental studi
of animal nutrition within the Organization. T
research in this field has been confined mainly to t
nutritional biochemistry of the sheep and the influen
of nutrition on wool production.

Division of Biochemistry and General Nutrition.
Application of the results of the investigations of th
Division to the practical problems of the sheep indust
continues to yield economic dividends which in rece
years have been most spectacular. Initially there w
the demonstration that areas in southern Australi
hitherto abandoned as useless for agriculture, can
transformed for efficient production when trace eleme
deficiencies of zinc and copper have been rectified.
a corollary to this discovery, and by virtue of th
complementary work on pasture improvement carri
out by the Division of Plant Industry (*see* Chapt
III.), it is now clear that vast areas of the Australia
continent, particularly in low rainfall regions, ca
similarly be rendered more productive after tra
element adjustments have been effected. The resul
of these experiments have indicated the way for develo
ments of great economic significance, and the knowled
obtained from many other researches in the field
nutrition is finding its way steadily into practice.

Some of the major projects undertaken by th
Division are described in this Chapter, and furth
detailed references are made under Chapter II
Section 11, and Chapter VII., Sections 2-8.

2. Nutrition and Wool Production.

(Division of Biochemistry and General Nutrition.

The findings of a series of researches into the effec
of nutrition on wool production conducted in th
Division are summarized very briefly hereunder.

The rate of wool production by the sheep is dete
mined by the level of its nutrition; the efficiency of th
sheep as a converter of fodder to wool fleece can
influenced materially by the level of nutrition during i
early stages of growth.

Wool fleece is produced from two morphologically tinct types of follicles, the primary follicles, so led because they are the first to appear in the skin the embryo and cease to be developed after about 90th day of foetal life, and the secondary follicles, development of which begins somewhat later d continues until the lamb is a year or more of age. e former are distributed over the wool-bearing sur- e in discrete groups of three around which a riable number of secondary follicles develop. The al numerical relationship between these two types follicles, and to the total population of follicles in the in of the adult sheep, while primarily an hereditary aracteristic has been shown unequivocally to be bject to modification by the nutritional status during owth and development; malnutrition during this riod seriously retards the differentiation of secondary licles, and materially decreases the final number of licles laid down in the integument. Thus both the bsequent efficiency of the sheep as a wool producer d the type of wool it produces are profoundly luenced by the level of nutrition early in its life.

These experiments have shown that early malnutri- n may reduce the total population of wool-producing llicles in the integument to 20 per cent. or more low the number that would develop had optimal trition allowed the lamb to express its full hereditary opensity. The manifest influence that the nutritional tus during the early stages of growth has on the bsequent size and conformation of the sheep, and ecially on the nature and growth of its skin, has w been clearly revealed. The nature and degree of dification of the adult sheep by early nutritional fluences is now much better understood; and the eans of overcoming serious impairment of the wool- oducing efficiency of flocks imposed by the nutritional vironment are clearly indicated.

Irrespective of the wool-producing efficiency of the ult sheep, the rate at which it produces wool clearly pends upon the nature and quantity of the food it nsumes. Experiments briefly discussed in previous ports have led to the recognition of the special tritional requirements of the proliferating cells thin the wool follicles, and of the processes involved conversation of these cells by keratinization to wool res, and have revealed the interplay of physiological ents which determine the overall rate of wool produc- n. Practically all of the major research projects at have been undertaken by this Division, although ncerned broadly with such apparently diverse subjects protein metabolism, energy transactions, minor ment requirements, rumination processes, &c., have nverged to illuminate the long chain of complex ents which underlie the production of wool fleece. e experimental findings have provided a solid undation of precise knowledge, an essential basis for e understanding and solution of many of the problems wool production encountered in the pastoral industry. far the greatest contribution to this knowledge has operly come from the efforts of Australian scientists, d much of the work that they have done has been pported directly or indirectly by funds provided by e Australian pastoral industry.

The current researches being conducted in this vision to illuminate further the processes involved in ol production are briefly discussed in Chapter VII., ction 2.

. Studies of the Metabolic Processes of Sheep.

(Division of Biochemistry and General Nutrition.)

A reasonably complete knowledge of the physiological d biochemical mechanisms by which the sheep con- rts its fodder into its own body substance and into wool fleece is an essential prerequisite for the understanding of metabolic and nutritional disturbances which at times seriously limit the health and productivity of sheep.

Ruminants, unlike the carnivores and mixed feeders, derive most of the energy necessary for their living processes from simple fatty acids which are formed in the paunch by bacterial fermentation of the fodder. For this reason the metabolic channels through which fatty acids are dealt with are particularly important in the sheep. As there is little exact knowledge of these metabolic pathways which have developed to a unique degree in ruminants, experimental work is devoted to this aspect of comparative biochemistry. Some of these investigations are described in Chapter VII., Sections 3-5.

4. Energy Metabolism of Sheep.

(Division of Biochemistry and General Nutrition.)

A sound knowledge of the overall thermodynamics of the production and utilization of the energy liberated by the oxidation of the foodstuffs in the animal's tissues is essential to the understanding of its nutritional physiology. Both the overall energy transactions and the intermediary energy metabolism of the sheep present many novel features, and as these were not understood a long-term research into this aspect of ruminant physiology was undertaken.

Much basic information has resulted from several years' intensive study of the energy transactions which take place in the digestive tracts and in the tissues of sheep that have been fed under meticulously controlled conditions, and knowledge of the energy metabolism of the sheep is now probably more complete than that of any other animal. Theoretical considerations based on these experimental data have clarified and advanced, more than a little, the understanding of the biochemical mechanisms involved in the liberation and utilization of energy by living processes.

Many of the findings have found immediate application in the practical husbandry of drought feeding. The amount of any particular fodder necessary to maintain sheep in a healthy condition over long periods may now be computed precisely and economic feasibility of hand-feeding thus assessed with much greater confidence.

The current experiments are briefly reported in Chapter VII., Sections 4 and 5.

5. Chronic Fluorosis in Sheep.

(Division of Biochemistry and General Nutrition.)

The waters of many deep artesian bores in the semi-arid pastoral country contain concentrations of fluorides that approach or exceed what are now known to be the limits of safety for potable stock-waters, and the toxic hazards are enhanced by evaporation from the open bore-drains in which these waters are reticulated. Sheep whose drinking-water is derived from these sources suffer serious disabilities: their teeth become badly affected, excessive wear and sometimes fracture of the incisors renders prehension difficult, and mastication becomes impossible because of selective abrasion of the molars. Consequently the grazing flocks do badly and many individuals die of inanition. Removal of the fluorine from such large volumes of water is not economically feasible; consequently some years ago, in an attempt to evolve husbandry methods to deal with the situation, a series of experimental investigation were initiated on the effects of dosing sheep over long periods with the quantities of fluorides they would ingest were they confined to these fluorine-bearing waters. Details of the interim findings have been published and are summarized in previous Reports.

As this investigation is virtually completed, a brief general summary is now possible. Waters containing fluorides in concentrations equivalent to 10 p.p.m. fluorine have definitely been proven to be harmful to grazing stock. All of the dental lesions observed in sheep grazed in the affected areas have been reproduced experimentally by administering fluorides to sheep confined under controlled conditions in pens or in small flocks at the Division's central field station. These experiments have shown that the untoward effects of chronic fluorosis on the general well-being of the sheep undoubtedly arise primarily from the teeth lesions, and that direct toxic effects are not likely to be encountered in animals confined under natural conditions to areas where artesian bores provide the sole source of drinking-water.

As fluorides do not pass through the placenta to the foetus or into the milk in sufficient quantities to lead to any untoward effects in the dentition of the lamb, mature ewes may be lambed with safety in the affected areas, provided that the flocks are removed before the lambs begin to drink the fluoride-bearing waters. The dental lesions which subsequently cause chronic fluorosis originate when the teeth are being formed; sheep which have no access to these waters until their permanent teeth are erupted suffer no disability, even when the fluoride content of their drinking-water is at least double that which would lead to dental lesions in younger sheep.

These experiments have considerably increased the knowledge of the effects of fluorides on teeth and bone formation, and in turn have clearly indicated husbandry procedures for avoiding the untoward effects of fluoride-containing waters.

6. CAROTENE AND VITAMIN A IN SHEEP NUTRITION.

(Division of Biochemistry and General Nutrition.)

The welfare of sheep under natural grazing conditions is probably more likely to be limited by a deficiency of vitamin A than of any other accessory food factor. Although carotene, the precursor of this vitamin, occurs in relative abundance in all green plants it is sensitive to oxidation and to irradiation by sunlight, so that dry pastures usually contain only very small quantities which frequently are insufficient to meet the nutritional needs of grazing stock.

Ten years ago little was known of the vitamin A requirements of the sheep or of the disabilities which ensue when the fodder is not capable of fulfilling these requirements.

The investigations which were initiated to provide this knowledge entailed a series of long-term experiments, as the vitamin is stored in the tissues and these depots are depleted to the low levels at which deficiency symptoms appear only after the experimental sheep have been confined to deficient rations for a year or more. The experiments have now been completed. The results cogent to sheep husbandry may be summarized very briefly as follows.

An abnormally low vitamin A status, as indicated by a very low concentration of vitamin A in the blood and by the clinical signs of night-blindness, appears in young sheep after they have been confined to vitamin A-deficient diets for about eight months. After a further four months food consumption begins to decline, the animals lose weight, and signs of muscular incoordination, &c., develop as the terminal symptoms of vitaminosis A. Older animals, with larger stores of vitamin A in their livers, withstand the first effects for at least sixteen months but subsequently decline rapidly. An intake of 25-30 μg. of carotene/kg. body wt./day is barely sufficient to prevent the symptoms; double this intake will fulfil the requirements and also allow some storage to proceed.

The grazing animal's capacity to lay down stores of vitamin A in its liver is obviously of prime importance to its well-being. When the animal is on green fodder its intake of carotene is high enough to ensure that sufficient storage is effected in a few months to maintain the animal over considerable periods of dry grazing when the total intake of carotene is low. This buffer
against deficiency enables lambs to graze without
effects for six months or more on seriously defici
fodder, and grown sheep to withstand dry-graz
conditions for at least a year.

To secure a normal vitamin A status of sheep o
extensive periods of hand-feeding during drought w
at the beginning the vitamin A store in the liver mi
be expected to be short, an intake of 50μg. of ca
tene/kg. body wt./day is necessary to meet all requi
ments, including those of reproduction. Allowing
a safe margin of 100 per cent., this would indicate t
a grown sheep needs 5 mg. carotene/day, so tha
fodder containing 5 mg. carotene/kg. may be conside
quite adequate in this respect. Good cereal-hay ch
usually has a higher carotene concentration than th

In general, the welfare of flocks grazing under natu
conditions is rarely limited by vitamin A deficien
When the normal seasonal cycle prevails, with interv
of four months or more of green grazing each ye
grazing sheep are unlikely to experience vitamin
deficiency; and even when the seasonal conditions
such that a period of new growth of pasture is miss
the animal's stores of vitamin A are usually suffici
to fulfil the requirements until the rains come. W
drought continues for longer periods the amount
available fodder is usually insufficient to support
flocks, so that a supplement of carotene alone in th
circumstances will be of little value. If, howe
supplements of grain are provided during long peri
of drought, an additional supplement of carotene
indicated, especially for young sheep and breeding ew

7. SALT TOLERANCE OF SHEEP.

(Division of Biochemistry and General Nutrition.

There is little sound knowledge of the extent to wh
sheep can tolerate the ingestion of considerable amou
of sodium chloride for long periods, or of how far
tolerance is influenced by the ingestion of other salt
carbonates, sulphates, and chlorides of calcium
magnesium, &c.—that occur in varying concentrati
in the bore-waters upon which the grazing of much
the semi-arid Australian pastoral lands depe
Information on the potability of drinking-waters
grazing stock has been based almost entirely on q
tionnaires which have depended on observations m
in such variable circumstances of climate, of availa
fodder, and of composition of waters as to lead to q
widely divergent views.

As a considerable reduction of the salt concentrat
in bore-waters is now economically feasible, and as
costs of treatment will depend primarily on
much of the dissolved salts must be removed to ren
the more saline waters potable, the importance o
more precise knowledge of the tolerance limits of p
bility of stock-waters is obvious.

A series of experiments have been initiated to prov
this information, and to study the long-term effects
saline waters of various compositions on the well-be
of sheep.

8. STEREOCHEMISTRY OF CARBOHYDRATES.

(Division of Biochemistry and General Nutritio

A survey of the reactions and properties of
anhydro-sugars and of the cyclic acetals of sugars
sugar alcohols has indicated that, almost without
ception, the structural and stereochemical features
these compounds may be explained by a few simple r
that are closely comparable with rules covering
properties of alicyclic compounds. The reactions of
cyclic carbohydrate derivatives are in many resp
complementary to those of the steroids and terpe
The recognition of these facts has already shown po
bilities of far-reaching applications to the synthesis
partially substituted sugars and of hitherto rare
inaccessible sugars. Particular attention has been p
to the properties of the 1, 3-dioxan ring.

A number of cyclic acetals of mannitol, sorbitol, cose, and galactose have been prepared, to serve as dia for further examination of the properties of ring ucture and as starting point for the synthesis of e sugars such as ribose and allose; and the effects of ious acid catalysts have been compared in an en- vour to improve methods for the preparation and ective hydrolysis of cyclic acetals.

Knowledge of the stabilities and reactivities of cyclic bohydrates has application in preparative work, and y also be of fundamental importance in the chemistry enzyme action.

MINOR ELEMENT DEFICIENCIES IN ANIMALS AND PLANTS.

ivision of Biochemistry and General Nutrition.)

The studies of the deficiency states which supervene en the minute requirements of copper, zinc, &c., essary for the complete nutrition of plants and imals are not fulfilled, have been discussed in pre- us Reports. These studies cover a wide field and k *inter alia* a more complete understanding of the ysiological functions that these elements serve in ing tissues.

A series of studies of cobalt and copper deficiencies the sheep is referred to in Chapter VII. The experi- nts reported below, while for the most part directed adly to this end, have been conducted with small imals under controlled laboratory conditions.

(a) *Copper Deficiency.*—The effects of copper iciency and those of molybdenum, sulphate, &c., on metabolism of copper in rats have been studied ther, with results that illuminate the problems ociated with induced copper deficiency in grazing ninants. The effects of feeding small (though rela- ely large) amounts of molybdate to rats whose intake copper is only just adequate for normal growth are se of a marginal copper deficiency, though the con- tration of copper in the blood is raised approxi- tely fivefold. This phenomenon is similar to that erved in experimental sheep grazed at the Division's d station at Robe, and discussed in previous Reports. ien sulphate is superimposed in concentrations that quite innocuous in the absence of molybdenum, the ic symptoms of the molybdenum are very greatly anced. Under these circumstances the additional phate has no effect on the copper concentration in blood or tissues.

Parallel experiments with ruminants show conclu- ely that additional sulphate decreases the toxicity of lybdenum without exerting any marked effect on the pper metabolism. These latter are described in apter VII., Section 6.

(b) *Zinc Deficiency in Animals.*—The techniques lved for the almost complete removal of zinc from dstuffs were discussed in the previous Report. Pre- ration of rations by these methods has rendered ssible the study of the essential function that zinc umes in living processes.

During the last year attention was devoted mainly to erall physiological effects of zinc deficiency in the rat. ired-feeding experiments with rats on these rations ealed that zinc deficiency led to a serious depletion both fat and protein beyond that accounted for by reduced food intake; and determinations of the erall rate of energy dissipation under basal conditions licated that zinc deficiency led to a marked rise in tabolic rate and so to a considerable decrease in the ciency of food utilization.

(c) *Zinc Deficiency in Plants.*—In contrast to pre- us observations, a state of zinc deficiency was found t to influence the aldolase activity in the leaves of ts; in the leaves of other plants, viz. subterranean ver, strawberry clover, and Yorkshire fog, zinc deficiency leads to a lowered aldolase activity per unit weight of leaf. In partially purified aldolase preparations homocysteine and *o*-phenanthroline were observed to inhibit the enzyme, and the addition of zinc failed to reactivate it. The chelating reagents disodium versenate and sodium diethyldithiocarbamate had no influence on aldolase activity. Partial removal (40 per cent.) of zinc from aldolase preparations brought about only insignificant reduction of the activity of the final preparations, and further purification led to the reduction of zinc concentrations to very low levels which would imply that if the molecule of the enzyme contained one atom of zinc it would have at least ten times the molecular weight determined by physical means. Thus it is probable that aldolase neither contains zinc nor requires zinc for its activity.

10. VITAMIN B_{12}.

(Division of Biochemistry and General Nutrition.)

(a) *General.*—The experiments discussed in the previous Report provided unequivocal proof that the effects of cobalt deficiency in ruminants are in fact the effects of a deficiency of the cobalt-containing accessory food factor, vitamin B_{12}, which is produced by the rumen flora in adequate amounts to fulfil the animal's requirements only when the fodder contains sufficient cobalt. Some of a considerable number of other studies of this and related phenomena are outlined below.

(b) *Microbiological Estimation of Vitamin B_{12}.*—Mention has been made of the important contributions that studies in microbiology and of the methods of microbiological assay have made to the understanding of cobalt deficiency in ruminants. These studies have been continued, and have been applied with striking results to the study of vitamin B_{12} metabolism in the sheep.

The bacteria *Lactobacillus leichmannii* and a methionine-requiring mutant of *Escherichia coli,* and a protozoan, the crysomonad *Ochromonas mahlemensis,* have been used as assay organisms to determine the production of vitamin B_{12} and of the cobalts containing B_{12}-like substances in the intestinal tract, and to investigate the absorption and utilization of vitamin B_{12} by the animal. The results of these experiments are referred to in more detail in Chapter VII.

(c) *Vitamin B_{12} Requirement of the Rat: Animal Assays of Vitamin B_{12}.*—A series of experimental attempts to induce extreme vitamin B_{12} deficiency in rats has been carried out. The results are of far-reaching importance to the understanding of the physiology of vitamin B_{12} absorption.

(d) *Vitamin B_{12} and Haemopeiesis.*—Studies of the anaemia which is almost invariably a marked terminal symptom of vitamin B_{12} deficiency in sheep under conditions of natural grazing of cobalt-deficient pastures have been continued. Sheep confined in metabolism cages or in pens on cobalt-deficient rations do not always become anaemic; many die of inanition due to lack of vitamin B_{12} before they develop any marked blood dyscrasia. Thus the metabolic defect which leads to breakdown of the capacity to produce red cells is subsidiary to the defect which underlies the failure of appetite.

The studies of porphyrin metabolism in normal and vitamin B_{12}-deficient sheep have been continued. Protoporphyrin synthesis is not influenced adversely in vitamin B_{12} deficiency. The investigations render doubtful the occurrence of coproporphyrin in the red cells, and thus throw open to question current theories of porphyrin metabolism based on the supposed occurrence of coproporphyrin in normal and pathological erythrocytes.

11. Plant Nutrition.

(Division of Biochemistry and General Nutrition.)

A wide programme of experimental studies of the mineral nutrition of plants is being continued. Previous studies of the plant's requirements of copper and zinc defined and solved the basic nutritional problems that led to the dramatic development of the Ninety-Mile Plain in South Australia. Development of this terrain is now progressing rapidly and is penetrating virgin tracts far removed from existing agricultural areas. It is no longer practicable for this Division to seek out and deal with the many individual problems presented by small variations in the soil types, &c., that will be encountered during development. This is more properly a function of extension services. It is, however, an obvious duty to increase further the basic knowledge upon which the solution of individual problems of this nature will depend. Thus the experimental investigations of the overall basic problems are being actively pursued under the more intensive and more easily controllable conditions of the laboratory and glass-house. These experiments are briefly referred to in Chapter III., Section 10.

12. Field Stations.

(Division of Biochemistry and General Nutrition.)

The Division's central field station, "Glenthorne", a property of 600 acres situated about 11 miles from the main laboratories, is now developing rapidly into a fine tool for researches that involve relatively large numbers of sheep. The flocks there comprise about 1,000 strong-woolled Merinos and a nucleus flock of fine-wooled Havilah Merinos, and from these the animals required for experimental studies are drawn. The experiments on vitamin A requirements and on the effects of chronic fluorosis, &c., were conducted there.

Several other field stations are situated elsewhere on terrain where deficiencies occur; among these the field stations at Robe, and at Brecon in the vicinity of Keith, are the most active. The work proceeding on the field stations is discussed briefly elsewhere in this Report.

13. Phalaris Staggers.

(Division of Biochemistry and General Nutrition.)

This work is described in Chapter VII., Section 7.

14. Urea Nitrogen as a Source of Protein for Sheep.

(Division of Biochemistry and General Nutrition.)

This work is described in Chapter VII., Section 8.

VII. SHEEP.

1. General.

The sheep holds a unique position in the Australian economy. Wool is our major export, and primary products from the sheep industry such as wool, lamb, mutton, and hides comprise up to 45 per cent. of all Australian rural production. The sheep, too, allows of the use of vast areas of marginal land which it has not so far been practicable to use for other purposes. With a sheep population of over 125,000,000 Australia produces about one-quarter of the world's wool and about twice as much as any other country. More than one-half of the world's production of fine wool comes from our dry inland areas. Thus Australia has a vital interest in ensuring that wool can withstand the competition from artificial fibres. The remarkable success of the latter has been due in the main to the clear understanding, arising from research, of the physical and chemical properties of the new fibres. Moreover, the chemical industry established to produce them is planned as a co-ordinated and organized unit, which ensures maximum efficiency and minimum wastage at all stages.

It is a major aim of the Organization's integr
programme of research in aid of the wool indu
to investigate every phase of sheep and wool pro
tion: soils, pastures and nutrition, genetics, an
husbandry, wool processing, textile manufacture,
the exploitation of by-products. The Organiza
has been given responsibility for carrying out
extensive programme under the provisions of
Wool Use Promotion Act 1945. The Government
set aside funds earmarked for this purpose amoun
to almost £400,000 per annum in a Wool Rese
Trust Account. Further moneys for capital expe
ture are available from interest on the £7,000,00
the Wool Industry Fund.

Soil fertility is obviously of prime importance
outstanding results have been achieved in impro
soil infertility arising from minor element deficien
On the plant side, too, special emphasis has
placed on pasture improvement and weed con
The work of the Organization on soils, pastures,
related matters affecting the pastoral industry
carried out by the Division of Soils and the Divi
of Plant Industry (*see* Chapters II. and III.).

Work on the sheep itself has been undertaken wi
the Division of Animal Health and Produc
(Chapter V.) and the Division of Biochemistry
General Nutrition (Chapter VI.). The Division
Mathematical Statistics is closely associated with
breeding investigations (*see* Section 14 of
Chapter), and the Division of Entomology co-oper
in the field of animal pests and diseases (*see* Cha
IX., Section 9). The Animal Genetics Section's w
on sheep breeding is described in Section 15 of
Chapter.

The Organization's work in the investigation of
processing and wool textile problems is underta
at the Wool Textile Research Laboratories and
Division of Industrial Chemistry (*see* Chapter XV

2. Nutrition and Wool Production.

(Division of Biochemistry and General Nutriti

The general background of these studies and som
the recent broad findings have been discussed
Chapter VI.

During the period under review a critical study
been made of the causes which underlie the seas
variation in the rate of wool production by Me
sheep. These investigations entail long-t
experiments.

The metabolic lesion within the wool follicles wh
occurs in copper deficiency is being further inve
gated to throw light on the processes of keratinizat

During the year, the main studies on pro
metabolism and wool growth have been devoted t
further investigation of the influence of ove
metabolic rate on the efficiency of protein utiliza
for wool growth. A number of experiments have b
directed to the metabolism of the sulphur-contain
amino acids. In all, knowledge of the process of w
production has been increased materially.

3. Processes of Rumination.

(Division of Biochemistry and General Nutritio

Studies of the physiological and microbiolog
processes of rumination have been continued,
some of the findings are briefly mentioned below.

(*a*) *Distribution of Nitrogen Between the Proto
and Bacteria of the Rumen Contents.*—A techni
has been evolved for separation of the bacteria
protozoa which inhabit the rumen. When sheep
fed on cereal hay about four-fifths of the micro
nitrogen is present in the rumen bacteria. Separat
of the micro-organisms from the rumen contents
sheep that have been fed on lucerne hay prese
difficulties owing to the greater proportion of fi

ded solid material present, but reasonable assess-
ts of the partition of nitrogen by these methods
till possible.

)) *Digestion of Nitrogenous Compounds and Con-*
ion of Plant Nitrogen to Microbial Nitrogen in
Rumen.—Further studies have been made of the
plications introduced by the presence of micro-
inisms in the determination of lignin: nitrogen
os, upon which many of the experimental studies
hat goes on in the rumen depend. The considerable
in the ratio of nitrogen to lignin in the rumen
tents of sheep that have fed on lucerne hay has
1 traced to the formation of ammonia and of other
usible breakdown products of proteins in the rumen.
orption of ammonia through the rumen wall would
stitute virtually a complete loss to the animal.
s work is being continued.

c) *Amino Acid Composition of Microbial Proteins.*
The rumen fluid of sheep contains considerable
ntities of ammonia and of amino acids, and the
centration of these degradation products of proteins
been found to vary greatly according to the nature
the fodder. The concentrations of the individual
ino acids which are free in solution in the rumen
tents and which are in the proteins and in the
ious types of microflora present are being investi-
ed by a technique using ion exchange resins.
ther knowledge of this aspect of the rumination
cesses will greatly clarify the overall problems of
tein metabolism in ruminants. The critical and
sitive analytical methods that are being employed
the assay of amino acid mixtures were developed
where.

d) *Hemicellulose Bacteria.*—Further attempts to
ate the bacteria responsible for the breakdown of
nicellulose in the rumen emphasize the important
ibiotic relationships that prevail there.

4. Energy Metabolism of Sheep.

ivision of Biochemistry and General Nutrition.)

This aspect of the Division's broad programme of
dies that are primarily concerned with the
ysiology of the sheep has been briefly discussed in
apter VI.

During the period under review the calorimeters and
er equipment have been employed mainly for
iodic determinations of the total energy exchange
sheep fed at a constant level throughout the year,
order to provide essential data which will allow
physiological basis of seasonal variations in wool
wth to be assessed.

The apparatus was also used for the determination
the energy transactions of experimental animals
ployed for a study of the metabolism of sulphur-
itaining amino acids in the nutrition and wool
wth series.

5. Carbohydrate Metabolism.

ivision of Biochemistry and General Nutrition.)

There is now much evidence to support the
pothesis that in certain respects the enzymic pattern
ich determines the intermediary metabolism of
ninants differs quantitatively at least from that of
ier classes of animals. A detailed knowledge of
se differences is of considerable theoretical interest,
l they are of prime practical importance, for upon
better knowledge of them the understanding of
tabolic diseases which affect sheep largely depends.

(a) *Pyruvate Levels in the Blood.*—The main
erest of these studies has centred around the observed
ferences in the metabolism of carbohydrates in young
ibs and adult sheep. During the period under review,
inges in the concentration of pyruvate in the blood
ich supervene on injection of glucose were studied
in young lambs, adult sheep, and a non-ruminating animal, the rabbit. In all animals the rise in level of pyruvate was roughly parallel to the blood glucose tolerance curves; it was similar in the rabbit and lamb and was quite distinctly different in the adult sheep. The phenomenon is thus closely associated with the relative inability of the tissues of the adult ruminant to utilize glucose.

(b) *Insulin Hypoglycaemia in Ruminates.*—A study of the relative tolerances of young lambs and adult sheep towards insulin has been made and marked differences have been revealed.

(c) *Hexokinase Activity of Intestinal Mucosa and Brain.*—The mechanism of utilization of glucose is being investigated by measuring the hexokinase activity of the intestinal mucosa and in the brains of adult sheep, of young lambs, and of other animals. The tissues of the adult sheep are less active in this respect than similar tissues of the rat. The activity in the tissues of the young lamb is low, but is increased materially as soon as the lamb is allowed to suckle.

(d) *The Effect of Pancreatectomy in Sheep and Lambs.*—Surgical procedures for the successful removal of the pancreas from ruminants have now been developed, and a number of animals have been rendered diabetic by this procedure. A study is being made of the severity of the symptoms and of the metabolic blocks involved in the upset entailed in sugar utilization.

(e) *Toxicity of Fluoroacetate in Ruminants.*—The poison fluoroacetate exerts its toxic action by impairing the metabolic channels through which sugar and the lower fatty acids are oxidized. Sub-lethal doses lead to muscular tremors and convulsions in the sheep. A study is being made of the mechanism of the toxic action in the sheep, in part to illuminate the carbohydrate metabolism further and in part to throw light on the toxic action of certain poison plants.

6. Minor Elements in Animal Nutrition.

(Division of Biochemistry and General Nutrition.)

(a) *Cobalt Deficiency in Ruminants.*—The following is a very brief summary of the results from a series of experiments on various aspects of cobalt deficiency conducted by the Division during the past year. Experiments with small flocks depastured on terrain where the pastures are short of cobalt, and with small groups of sheep confined under controlled laboratory conditions to cobalt-deficient rations, have proven unequivocally that the untoward effects which supervene in sheep when their fodder provides less than 0.1 mg. Co/day are due to a deficiency of the cobalt-containing vitamin B_{12}, an accessory food factor produced in considerable quantities by micro-organisms in the paunch.

Withdrawal of cobalt from the rations leads within four days to very material changes in the rumen flora; the numbers of vitamin B_{12}-producing microorganisms which flourish there when the cobalt concentration in the fodder exceeds 0.03 p.p.m. dry matter fall precipitately, and the production of vitamin B_{12} is reduced to less than a tenth of the amount produced in the presence of ample cobalt. The production remains at this low level indefinitely so long as extra cobalt is withheld. Reinstatement of a higher cobalt concentration in the rumen contents results in a rapid proliferation of the vitamin B_{12}-producing flora with a consequent rise in the production of vitamin B_{12}.

A series of experiments has proven that less than 5 per cent. of the true vitamin B_{12} produced in the rumen is absorbed from the alimentary tract of the sheep. The reasons for this poor absorption are being investigated further. The absorbed vitamin is stored in the tissues, mainly in the liver, which normally contains about 2 μg./g. wet weight—sufficient to provide the full nutritional requirements of the mature animal for six months or more, even under feeding conditions in which little or no further vitamin B_{12} is produced in the rumen. About 6 μg. vitamin B_{12} is lost each day during the normal course of metabolism, so that the duration of the period that a mature sheep can be depastured on cobalt-deficient pastures before it shows the first symptoms of deficiency depends directly on the extent of the depots of vitamin B_{12} in its liver. These latter observations render clear the reason why sheep on incipiently cobalt-deficient pastures suffer so rapidly when the cobalt intake falls in certain seasons to less than the critical level at which the production of vitamin B_{12} is seriously reduced. Many of the problems associated with cobalt deficiency have become clarified from this series of experiments.

(*b*) *Copper Deficiency in Sheep.*—Many of the long-term experiments conducted in the field and in the laboratory to extend knowledge of the copper metabolism of sheep have been discussed briefly in previous reports. During the past year one of the main activities has related to the effects of molybdenum on the copper metabolism of the sheep and to the effects which supervene when considerable doses of sulphate, &c., are imposed on relatively high intakes of molybdenum.

Molybdate equivalent to 100 mg. Mo/day very considerably increased the concentration of copper in the blood of sheep grazed at Robe but tended, paradoxically, to precipitate the symptoms of copper deficiency. Sulphate superimposed on the molybdenum reduced the molybdenum concentration in the blood without materially influencing the copper metabolism in the experimental sheep grazing at Robe. Similar experiments with experimental flocks grazed at "Glenthorne" indicated that molybdenum increased the rate of depletion of copper from the livers of the sheep during the seasons when the pastures contained insufficient copper to make good that lost in the normal course of metabolism, and decreased materially the rate of storage during the periods when the copper in the pastures was relatively high; but in no circumstances, either under field conditions or under the strictly controlled conditions of pens, did molybdenum reduce the copper stores of animals receiving 8–10 mg. Cu/day below the critical level at which signs of copper deficiency appear. Experiments concluded during the past year also showed unequivocally that ingestion of relatively large amounts of molybdate (equivalent 100 mg. Mo/day) by breeding ewes during the whole of their term of pregnancy and for a considerable period before did not adversely affect storage of copper in the foetal lamb.

The effects which supervene when sulphate is superimposed on molybdenum are complex, and at this juncture the results of many experiments indicate that sulphate certainly influences the rate of elimination of molybdenum, but only in very special circumstances that of copper. The toxic effects of molybdenum, however, are decreased by administering relatively small amounts of copper. Current experiments are aimed at throwing further light on this phenomenon.

These studies of the effects of molybdenum, sulphate, &c., on the storage and utilization of copper by grazing ruminants are likely to assume considerable importance in the understanding and control of "induced copper deficiency" in areas where the flocks develop the copper deficiency syndrome while grazing on pastures that contain sufficient copper to fulfil normally the full requirements.

7. PHALARIS STAGGERS.

(Division of Biochemistry and General Nutritio

The field station established in the Ninety-mile Pl
at Brecon, near Keith, South Australia, on an a
typical of the deficient terrain that is being develo
in this region according to procedures indicated by
Division, has been described in previous Reports. T
present activities there are devoted to experimen
studies of the growth, production, and general welf
of sheep depastured on the three types of perman
pastures that are being used for the development
these deficient tracts. As the overall problems
pasture development there have been solved, empha
has been placed on study of the health of the flo
and herds on these newly developed pastures, so t
disabilities may be recognized and steps taken
rectify them before they assume serious proportio

Knowledge gained from experiments on simi
types of terrain elsewhere suggested that the cob
concentration of some at least of the fodder pla
grown on these areas might be insufficient to meet
full nutritional requirements of grazing sheep. Expe
ments designed to investigate this indicated in
first year that, whereas no evidence of cobalt deficie
appeared during that period in the individuals of
experimental flocks, a supplement equivalent to 1 r
cobalt/day administered as a drench once each w
completely protected the sheep from "Phala
staggers", a fatal malady with nervous complicati
that has been observed to occur spasmodically am
sheep and cattle when their grazing is confined ess
tially to the perennial grass *Phalaris tuber*
Although its potential danger has been recognized a
the nervous symptoms attributed to a toxic princi
in the young shoots of this plant, the malady had p
viously been observed only in a few areas and in th
infrequently. Serious outbreaks were unknown
most types of terrain where *Phalaris* is grown a
pasture plant. In the newly developed terrain of
Ninety-mile Plain, however, the malady assumes v
serious proportions. The protection afforded by
administration of cobalt *per os* has now been am
confirmed, and further experiments have indicate
reciprocal relationship between the amount of cob
ingested and the amount of toxic material that the sh
can tolerate.

Experiments during the past year have been ai
at determining whether the protective action of co
is effected within the intestinal tract or within
tissues. The concentration of cobalt in the rumen c
tents is known to influence very materially the nat
of the mixed population of micro-organisms that inha
the paunch, and it is conceivable that those favou
by cobalt have the capacity to destroy the toxic pr
ciple before it is absorbed. Alternatively the hig
vitamin B_{12} status of the tissues contingent upon
extra cobalt in the rumen might conceivably incre
metabolic destruction of the toxic material after it
been absorbed, and so prevent its concentration wit
the tissues to an extent that would influence the ne
cells. The former of these alternative hypotheses
probably correct; experiments have shown that
malady develops irrespective of the vitamin B_{12} sta
of the sheep; parenteral introduction of relati
massive doses either of vitamin B_{12} or cobalt it
affords no protection under circumstances in wh
cobalt *per os* will entirely prevent the malady.

In these particular areas the *Phalaris* remains t
until at least mid September; as the season advan
however, the growth of other fodder species in
pastures lessens the risk of the malady, because
amount of *Phalaris* consumed by the grazing shee
decreased.

Attempts to isolate the neurotoxic principle have not as yet been successful; the procedure would in our present state of knowledge involve large-scale operations, and the problem has been set aside *pro tem.* Neither the standing straw of *Phalaris* nor the tubers of the plant was toxic when taken as an entire ration over a period of three weeks by mature sheep in pens.

Treatment of *Phalaris* pastures in this area with 1 lb. of cobalt sulphate per acre in 1953 protected experimental flocks in that year, under conditions which led to a high mortality in a flock depastured on the immediately adjacent pasture that had not been treated. These experiments are being continued.

8. UREA NITROGEN AS A SOURCE OF PROTEIN FOR SHEEP.

(Division of Biochemistry and General Nutrition.)

The possibility that urea or similar simple nitrogenous substances might find useful application as substitutes for protein supplements for sheep has been discussed in previous Reports. Experiments with sheep in pens have shown that when the diet contains relatively large quantities of simple carbohydrates that are easily utilized by the rumen flora, additional urea stimulates the proliferation of the micro-organisms in the rumen, with the result that useful quantities of protein are formed and wool production is enhanced. It was stressed that the economic feasibility of urea supplements was doubtful and that recommendations for their use would depend on extensive trials under various conditions in the field. A series of trials carried out in conjunction with the Queensland Department of Agriculture and Stock at "Toorak" field station, Julia Creek, north-west Queensland, demonstrated the serious disabilities attendant upon the use of urea as a constituent of supplements fed under semi-drought conditions. Supplements of urea and grain proved unpalatable, and in some cases actually toxic to the grazing sheep.

The feasibility of feeding nitrogenous substances other than urea is being tested, initially by experiments with sheep under the controlled conditions of pens.

9. METABOLISM IN PREGNANT EWES.

(Division of Animal Health and Production.)

(*a*) *Pregnancy Toxaemia Investigations* (*Sheep Biology Laboratory*).—Blood analyses on laboratory-induced cases of pregnancy toxaemia in March, 1953, revealed the apparent presence of high levels of citric acid, but it was then found that the recommended method for its determination was subject to interference from the high levels of ketone bodies present in the blood of fasted pregnant ewes and of ewes with pregnancy toxaemia. This necessitated an intensive investigation of methods for estimation of blood citric acid levels. Methods for the determination of pyruvic acid were also closely investigated because peculiar results in that estimation appeared to indicate the presence of a keto-acid other than pyruvic, oxalacetic, and L-ketoglutamic acids in the blood of fasted pregnant ewes.

The only consistent feature recorded from a series of field cases of pregnancy toxaemia was a consistently much higher level of acetic acid in the blood than was found in fasted pregnant ewes which showed no clinical signs. Ranges found were: fasted non-pregnant ewes 1–3, fasted pregnant ewes 2–5, and mild cases of pregnancy toxaemia 8–15 mg.–100 ml. blood.

10. DROUGHT FEEDING AND RELATED PROBLEMS.

(Division of Animal Health and Production.)

In collaboration with the New South Wales Department of Agriculture, staff of the McMaster Laboratory continued experiments on drought feeding of sheep at Glenfield, New South Wales, with further substantial support by the New South Wales Graziers' Association from the Burdekin Bequest.

The chief results of the year's work may be summarized as follows:—

(i) After a period of eight months on drought rations, 4-6 tooth Merino wethers showed no permanent effects.

(ii) Wethers which received regular supplements of cobalt averaged 10 lb. heavier in body weight and their plasma contained 5 i.u. more vitamin A per 100 ml. than that of controls, but these differences were not statistically significant. It was found that 27–30 per cent. of vitamin A administered orally was stored in the liver.

(iii) The addition of 0.25 per cent. sodium chloride to rations which contained 50-100 per cent. of oat grain increased the rate of body weight gain by 19-58 per cent. It appeared that under the conditions of the experiment the sodium requirements of the sheep lay between 0.88 and 2.62 g. sodium per day, or about 0.1 per cent. of the diets.

(iv) One group of lambs was given access to a creep containing equal parts of lucerne chaff and oats, and a similar group of lambs received no supplement. There was no apparent difference between the lambs at six weeks of age, probably because the ewes in both groups took all day to consume their ration, which consequently was also available to the lambs.

(v) A further experiment concerned the effect of a small daily supplement of protein to sheep fed on cereal straw. The basal ration was a mixture of equal parts of cereal-straw chaff and wheaten chaff, which contained 3.5 per cent. crude protein. This was fed *ad lib.* in self-feeders. Sheep in six of the groups were given 4 oz./day of a concentrate mixture which contained 18.9 per cent. crude protein. The supplements were given daily, twice weekly, or weekly to three groups of twelve sheep, and three other groups of twelve sheep were fed individually in single pens. An additional group of sixteen sheep received no supplement. During the five months of observations the sheep of the control group lost 30 lb. in weight, and four of the sixteen died. The loss in weight of the groups which received the supplement was 5-12 lb. but there was no apparent effect attributable to the different methods of feeding. Measurements of food intake showed that the supplement increased the quantity of roughage consumed. The plasma vitamin A levels were low in all groups.

(vi) Seven groups of three-year-old Merino ewes were used to investigate the practicability of keeping adult sheep on sub-maintenance rations for extended periods. Oat grain plus 1.5 per cent. ground limestone was fed to all groups and one group received in addition 0.25 per cent. salt. The rates of feeding were 4.0, 3.0, and 2.0 lb. starch equivalent (S.E.) per head per week. Within each group, one subgroup was fed weekly and the other daily. Both subgroups given 4.0 lb. S.E. per week maintained weight during the seven months of observation and none died. The addition of salt had no appreciable effect. In the subgroups given 3.0 lb. S.E. weekly, about 10 lb. loss of weight occurred during the first month but thereafter the body weights were constant. Two sheep died in the subgroup fed daily. In both subgroups fed 2.0 lb. S.E. per week a steady loss of weight occurred. Four sheep died in the daily fed, and five in the weekly fed subgroups. It would appear that a ration of 3.0 lb. S.E. per week is adequate to maintain store condition for at least seven months under these conditions. It was found that increasing the ration of the survivors from the 2.0 and the 3.0 lb. S.E. subgroups to 4.0 lb. S.E. per week led to an increase of 7 lb. body weight in 40 days.

11. Toxicity of Large Rations of Wheat.

(Division of Animal Health and Production.)

In this condition, atony of the rumen ensues after a few hours. This may be due in part to the low pH; a study of the effect of low pH upon ruminal motility has shown that reduction of pH to near pH 4, as may occur after wheat gorging, considerably reduces ruminal motility. This work is being done at the Animal Health Laboratory, Melbourne.

Some further attention has been given to wheat toxicity in horses. It was found that when 10 g./kg. body weight or more was consumed by susceptible horses, lactic acid fermentation developed throughout the bowel, as in sheep. This was accompanied by mild acidosis and severe haemoconcentration, but only slight lactacidaemia. These systematic disturbances were not necessarily accompanied by laminitis. Marked laminitis developed in horses which consumed only 7-9 g./kg. body weight, but no evidence of predominantly lactic fermentation was found in the bowel at autopsy two to three days after feeding. A study is being made of the pathological histology of laminitis in these cases.

12. Infertility and Physiology of Reproduction.

(Division of Animal Health and Production.)

(*a*) *Seasonal Variation in the Level of Fertility in Merino Sheep* (*Animal Health Laboratory, Melbourne*).—(i) *Comparison of Mating Times.*—A flock of ewes, seven to eight years of age, was divided into two groups. One group was mated in June-July, the other in December-January. Of the animals joined in June, mating declined from an initially high level to a low level in the fourth week and it was estimated that 5 per cent. did not mate. Of those joined in December all mated and the incidence of mating increased to a high level in the fourth week. However, the incidence of mating did not attain, in either group in any year, the level of 6 per cent. per day characteristic of mating in March-April. The mating performance in December cannot be explained on the basis of stimulation of ovarian activity *de novo*, as ovulation and corpus luteum formation must have been proceeding in some ewes of the group at that time.

Some of the ewes were autopsied three to six weeks after mating. Of these ewes 92 per cent. in the one group and 87 per cent. in the other had normal uterine contents. The studies are continuing.

(ii) *Twin Births.*—Among Merino ewes, now five to six years old, in which 53 per cent. of twin births occurred from conceptions at the Werribee field station during May and June, 1952, there were 65 per cent. of twin births from conceptions in May, 1953, and 36 per cent. from conceptions in July. The proportion of twin births from conceptions in July, though lower than that from conceptions in May, was much higher than had been recorded previously from mating at that time. The proportion was also much higher than in ewes from another source, seven to eight years old, which were mated under comparable conditions in May. In these only 17 per cent. of the births were twin.

(*b*) *Failure in Conception and Early Embryonic Mortality in Merino Ewes.*—This study was extended to ewes at the Regional Pastoral Laboratory, Armidale, and the National Field Station, "Gilruth Plains". At both centres a number of ewes were autopsied three to four weeks after mating. Little evidence was found of failure in conception at Armidale. However, normal healthy foeti were present in only 31 of 37 ewes at "Gilruth Plains".

(*c*) *Seasonal Variation in Lactation.*—The present studies have been extended to embrace observations on seasonal variation in milk production and the course of lactation. Early observations suggest that when milk is allowed to accumulate in the udder for as long as 5 hr., the rate of secretion is retarded and the interval between test milkings must be reduced to 4 hr.

(*d*) *Mating in the Field.*—The occurrence and distribution of mating has been studied in sample groups of ewes from five Merino and two Corriedale flocks in the Western District of Victoria. The distribution of mating varied with the time at which the ewes were joined with the rams and with their prior treatment. During the first four weeks of the mating period, 85-90 per cent. of the Merino ewes joined in November, 1953, and 96-98 per cent. of those joined in December, 1953, and March, 1954, were marked by the rams. In two Merino flocks which were joined at the end of December and in March respectively, 94 and 96 per cent. of the ewes mated in the first week. Only 72 per cent. of maiden Corriedale ewes joined in mid-December, 1953, mated during the first four weeks and some did not mate until the end of March. Ninety-five per cent. of mature ewes from the same flock had mated in the first four weeks after joining at the end of December, 1952, and 94 per cent. of Corriedale ewes from another flock mated during the first three weeks after joining in March, 1953.

(*e*) *Mechanism of Fertilization* (*Sheep Biology Laboratory*).—(i) *The Reaction of the Zone Pellucida to Sperm Penetration.*—The zona pellucida of the rat egg, in common with the eggs of most animals, changes after the entry of the first sperm in such a way as to decrease the chances of a subsequent penetration. It has now been shown that in the rat egg this change took between 10 min. and 1½ hr. to reach completion.

(ii) *Induction and Inhibition of the Second Polar Division in the Rat Egg.*—Cold-shock and various anaesthetics caused emission of the second polar body in a large proportion of unfertilized eggs. This activation of the egg did not render it impenetrable to sperms, as was previously thought. Inhibition of the second polar division in penetrated eggs was induced by hot-shock or colchicine treatment. Hot-shock had a transitory effect but the effect of colchicine was prolonged. Hot-shock treatment of rat eggs would probably result in triploidy in some of the embryos, for there was a high incidence of dispermy in treated eggs.

When cold-shock treatment was applied to the eggs of unmated rats, almost 10 per cent. of the eggs were induced to undergo nucleus formation and early cleavage. This appeared to be an early form of parthenogenesis.

(iii) *The effect of Hot and Cold Shock Treatment on Mouse Eggs.*—In the mouse, cold-shock did not evoke the completion of the second polar division, but hot-shock did. Following hot-shock treatment, apparent early parthenogenesis involving reformation of nuclei and cleavage was seen in about half of the eggs from unmated animals. In mated animals many of the eggs underwent abnormal fertilization. Both types of eggs may be expected to give rise to triploid embryos, but by different mechanisms.

(iv) *Time Relations of Ovulation and Fertilization in Rats and Mice.*—The time relations of ovulation and the various stages in the penetration of eggs and the formation of pronuclei have been determined in rats kept under natural lighting conditions and in those kept in a cabinet in which "day" and "night" were reversed. In both groups, ovulation began about 6 hr. after the onset of darkness and was completed in about 4 hr. The other time relations were very similar in the two groups. The average interval between ovulation and sperm penetration was about 3 hr.

Similar time relations were found for mice kept in the same cabinet and using the same diurnal cycle.

(v) *Delayed Mating in Mice.*—In rats and rabbits, when mating is delayed until the time of ovulation or later, a considerable increase in the incidence of polyspermy is observed. However, in mice no such increase was seen.

In the rat, penetration of the eggs by sperms does not commence until two hours after delayed mating. This was taken to indicate that the sperms normally require to spend a period of about two hours in the female tract before they are able to penetrate the eggs. It has now been found that in the mouse the period required for this "capacitation" is only about one hour.

(vi) *Observations on Nuclear Size and Form in Rat and Mouse Eggs.*—Nuclear size and form in eggs that were very probably haploid, diploid, and triploid, were made and some conclusions were reached about the mechanisms involved in the regulation of pronuclear growth.

(vii) *Early Gynogenesis in Rats.*—Adult male rats were placed beneath a therapeutic X-ray machine and given doses of 500, 1,000, 2,000, and 3,000 r. The rats were subsequently allowed coitus and fertilized eggs were found in females inseminated by males which had received 500 and 1,000 r. The males which received higher doses rarely mated because of inflammation of the penis. These dose levels are being repeated with the penis protected.

(viii) *The Effect of Genistein on Fertilization.*—Sperm transport to the site of fertilization and the fertilization of the eggs appeared normal in rats given 2, 10, or 50 mg. genistein/week, or 0.2, 1.0, or 5.0 μg. oestradiol/week. A dose level of 50 mg. genistein/week, however, interrupted pregnancy in the later stages. None of six animals so treated gave birth to young, although they were allowed to remain with the males for five weeks. All showed evidence of foetal resorption. The effect of higher doses of oestradiol is being investigated.

(ix) *Comparative Studies.*—In co-operation with the University of Sydney, the distribution of sperms in the genital tract of dogs soon after mating was observed. In addition, the nuclear changes accompanying fertilization in dog eggs were studied.

The sperm morphology of several available species of marsupial (opossum, bandicoot, and tiger cat) was studied.

(x) *Histochemical Reactions of Mucopolysaccharides.*—Chondroitin sulphate, the acidic mucopolysaccharide from cornea, and the acidic and neutral mucopolysaccharides from gastric mucin were prepared, and preparations of hyaluronic acid, heparin, and the acid mucopolysaccharide from dentine were obtained from other sources.

The neutral compound stained strongly by the periodic acid-Schiff (PAS) technique, the acidic preparation from dentine stained moderately, but the remainder barely stained at all. It was concluded that the PAS reaction is of little value for the histochemical demonstration of acid mucopolysaccharides.

13. Breeding and Genetical Studies.

(Division of Animal Health and Production.)

(*a*) *Inbred Flocks of Australian Merinos (McMaster Field Station).*—(i) *The Flocks.*—The programme of inbreeding without selection is continuing. Sires leading three of the flocks have been replaced owing to their low fertility. This will result in a slight decline in the level of inbreeding (Wright's coefficient) for this year's lamb drop. A mean inbreeding coefficient of approximately 0.20 is expected compared with the level of 0.24 for the 1953 drop.

(ii) *Top-crossing.*—Data for mean birth and weaning weights from progeny by sires having inbreeding coefficients of 0.25, and their non-inbred half-brothers, born at Deniliquin, continue to show no differences.

(*b*) *Inheritance of Component Fleece Characters.*—Reciprocal matings of the parental generation were commenced this year, using Border Leicester rams from the stud which provided the original parental ewes, and finewool ewes from the stud which provided the original parental rams. Complete parental matings are now Border Leicester sires x finewool Merino ewes, and finewool Merino sires x Border Leicester ewes. F_1 progeny from this latter cross continue to be mated for the purpose of building up the F_2 population.

Further fleece data from the F_1 generation support the statement made previously that for the characters of yield and wax and suint ratio, mean values for the F_1's are similar to those for the Border Leicester parent. Mean values for staple length and fibre diameter continue to be of an intermediate nature, although closer to the Border Leicester parent. Mean values for number of crimps per inch and density of fibre population are more truly intermediate.

(*c*) *Fleece Rot.*—Results of observations were published during the year. Further work is in progress. Climatic data from a number of centres are being examined in order to delineate areas in which fleece rot is likely to occur. Other data from various sources show that strains of Merino sheep differ in the degree of their susceptibility to the disease and that these differences bear important relationships to climate.

(*d*) *Studies on Twins.*—(i) *Selection for Twinning.*—In conjunction with the Division of Plant Industry and the Division of Mathematical Statistics, a twin selection experiment has been commenced at Deniliquin. Twin-bearing ewes have been mated to rams born as twins, and single bearing ewes to rams born as singles, in a selection experiment (for and against twinning) designed to continue over several generations.

(ii) *Skin Follicle Comparisons between Twin and Single Lambs.*—In conjunction with the Animal Genetics Section two experiments are in progress to determine whether differences in follicle population per unit area, or in numbers of primary and secondary follicles, are observable between twin and single lambs during gestation and also during post-natal growth.

(*e*) *The Effect of Impaired or Imperfect Mammary Function of the Merino Ewe on her Ability to Raise a Lamb.*—Data which have been obtained over a four-year period have been analysed. The principal findings from the investigation are:—

(i) In a flock of ewes the number having defective udder function increases with age, rising from approximately 4 per cent. at two years to 16 per cent. at seven years.

(ii) After allowing for the effects of extraneous factors, it was found that ewes with defective udder function reared fewer lambs to weaning age than those with normally functioning udders. Their lambs were also lighter at weaning, made smaller daily gains in weight, and, in the one year when they were not shorn as weaners, cut less greasy wool per head.

(*f*) *Strains of Merino Sheep in Several Environments.*—This project is continuing satisfactorily at the three field centres. Standard observations and measurements are being made and subjective fleece gradings by a worker from the East Sydney Technical College are being continued.

Numbers of sheep in each of the strains have been reduced to not more than 100 ewes of all ages per strain per station.

Semen examinations of rams to be used in the trial at all stations have been continued. An exchange of rams between stations has been carried out with the aim of maintaining genetic uniformity.

An analysis of the data for the 1950-51 season from the purchased ewes gave results similar to that of the previous season in that strain x location interactions were highly significant in most characters. Most of these interactions were small in size compared with the main effects of strain and location.

Data from the group feeding experiment mentioned in last year's Report have been examined. In terms of weight of wool produced per unit of net energy consumed over a period of four months the differences between strains were not significant. They were in the direction of the strong-woolled strain being most efficient and the fine-woolled strain least efficient.

(*g*) *Hornedness in Sheep.*—These studies, commenced in 1951 at "Gilruth Plains", have reached the stage where the first F_2 animals have been inspected as weaners. On the basis of these and other observations, a working hypothesis has been formulated which suggests that polledness is dominant to hornedness in both sexes in the Merino sheep used in this experiment.

In addition to the mating planned specifically for the study of hornedness, all ewes in some of the other trials mentioned, numbering some 1,500, are scored annually for degree of hornedness. From these data it is hoped to demonstrate whether or not hornedness is associated with any fleece characteristics or any aspect of fertility.

14. Sheep Beeding.

(Division of Mathematical Statistics.)

The Division of Mathematical Statistics has continued to work in collaboration with the Division of Animal Health and Production in studies on sheep breeding.

(*a*) *Progress of Project AB*1.—This project, the main one of the studies, was reorganized during the year. It consists of two parts, one being of three closed breeding groups with three different methods of sire selection, the other of paired closed breeding groups in which selection is for high and low values of single characters.

In dealing with heritabilities as high as those found with characters of the Merino, only a small advantage is to be gained by the use of family tests, but despite this it was considered advisable to continue the sire selection groups in the experiment, with modifications in the number of sires and ewes used. This adjustment made it possible to extend the work on the family series, and consequently five new pairs of groups were added to the two mentioned in the last Report, the new characters under selection (for high or low values) being clean wool weight itself, fibre diameter, wrinkling score, wool weight per unit area of skin, and percentage clean-scoured yield.

(i) *Heritability and Correlation Estimates.*—Further heritability estimates from the sire selection series have confirmed the high values previously found for wool weight and its components. Results from the family series also confirm these high estimates, the progeny in most groups showing even greater movement in the direction of selection than would be expected from the heritability figure.

Follicle counts per square centimetre on skin sections at birth and at 15-16 months, from progeny in the high and low fibre number groups, have shown differences not only in the number of secondary follicles and the secondary: primary follicle ratio, but also in the number of primary follicles.

The contribution to clean wool weight of each of the five components (body size, wrinkling of skin, fibre number per unit area, staple length, and fibre diameter) has now been analysed for ewe progeny born in each of five years. The importance of high fibre number as a source of increased wool weight has been clearly demonstrated in four of the five years, but in the fifth year fibre number had very little influence on wool weight. In this year feed conditions were bad, the ewes were small, fibre numbers per unit area being correspondingly high, and wool weights were low, with less variation than in other years.

(ii) *Influence of Age on Production.*—With the emphasis now laid on selection by the individual's own performance, accuracy of measurement of that performance is essential. In general, rams will be selected at the earliest possible age, but comparison of rams at different ages may sometimes be necessary. It is planned to keep all rams in the control series until six years of age, full measurements being made on them annually. Information on age changes will then be available.

Observations on changes in production with age of the ewe are being made up to ten years of age. Data for the older age-groups are so far scanty, but there is an indication of slight decline in survival rate and weaning weight of lambs after the ewes reach an age of eight years. At nine years of age, the percentage of lambs weaned to ewes mated, and the mean weaning weight of the surviving lambs, are still higher than for maiden ewes, but in the only records yet available for ten-year-old ewes both these production measures are lower than for the maiden ewes. Clean wool weight in eight and nine year-old ewes is about 1½ lb. below that for two to three year-old ewes.

Information on changes in production with age has been used to calculate production tables based on different ages for casting ewes.

(*b*) *Additional Selection Trial.*—One of the main problems in the Merino industry is the low lambing percentage frequently obtained. A possible solution would be increased twinning, even if in some environments twins are inferior to single lambs. Four groups were mated at the Regional Pastoral Laboratory, Deniliquin, in May, 1954; in two of these, selection will be for ewes bearing twins, and in the other for ewes bearing singles. Later, when numbers build up, the groups will be split over two environments.

The experiment will give information not only on the possibility of increasing twinning through selection, but also on the repeatability of twinning, and on the maternal influence of twin ewes on the productivity of their offspring, both for wool and lambs.

15. Genetics of Sheep.

(Animal Genetics Section.)

The experiments outlined in last year's Report continue satisfactorily. The experiment to determine the age at which the primary: secondary follicle ratio in Merinos becomes markedly different from that of other breeds has been completed. A new experiment has been launched in collaboration with the Dickson Field Station of the Division of Plant Industry to determine the heritability of primary: secondary ratio and to estimate the extent to which environmental variance in this character can be measured and discounted in breeding work.

16. Biological Studies of Skin and Wool Growth.

(Division of Animal Health and Production.)

(*a*) *Comparative Studies of Breeds of Sheep (Sheep Biology Laboratory).*—The statistical analyses of the study of Lincoln, Corriedale, Polwarth, and Fine Merino ewes mentioned in earlier Reports have been concluded.

The annual returns of registered breeders to the Australian Merino Stud Flock Register have been tabulated for the years 1921-1950, and some analyses completed. One of the most outstanding points emerging from this analysis has been the great genetic importance to the industry of a relatively limited number of "parent" studs from which a high proportion of stud and flock rams is derived.

(*b*) *Endocrinology of Wool Growth.*—(i) *Wool Growth and the Anterior Pituitary Gland.*—Work has been continued on the fractionation of anterior pituitary extracts and the capacity of these extracts to restore wool growth in the hypophysectomized sheep. Preliminary evidence suggests that ox growth hormone is electrophoretically distinct from sheep growth hormone.

Problems of the application of zone electrophoresis to pituitary proteins are being examined. The conditions most suitable and widely used for the analysis of plasma protein have been found unsatisfactory for pituitary proteins.

(ii) *Wool Follicle Development and the Thyroid Gland.*—Thyroidectomy of the new-born lamb has been shown to suppress the completion of wool follicle development. Administration of thyroxine prevented this effect. The extent to which the degree of follicle development is determined by the level of thyroxin secretion is being examined.

(iii) *Wool Growth and the Adrenal Cortex.*—An experiment on the influence of the adrenal cortex on wool growth was carried out by observing effects on wool growth and on the adrenal cortex of the administration of D.D.D. (2, 2-bis (-*p*-chlorophenyl)-1, 1-dichloroethane). No effects on wool growth have yet been produced but it remains to be seen whether D.D.D. has produced the histological changes in the adrenal cortex reported for dogs and rats.

(iv) *The Relation of Wool Growth to Environmental Light and Temperature.*—Preliminary observations have been made in an experiment designed to analyse the relative contributions of heat and light to the seasonal cycle of wool growth.

(*c*) *Experimental Histology of Skin and Hair.*—(i) *The Blood Supply of the Skin and Hair Follicles in Sheep and Other Mammals.*—A study has been made of the distribution of blood vessels to the skin and various types of hair follicle and the effect of fluctuations in blood flow on growth of hair. An injection technique (using Indian ink) has been used to study the distribution of the blood vessels in the skin of sheep, rats, and mice, and a transparent chamber technique has been successfully applied to one mouse, a photographic record being made of the changes in the skin blood vessels. These observations, which will be continued, have important implications for several problems of the biology of skin and hair.

(ii) *Growth of Sheep Skin and Wool in Tissue Culture.*—The commencement of this investigation was reported previously. Skin from sheep foetuses of 80, 100, and 120 days' gestation has now been cultivated for 16, 16, and 11 days respectively, in a medium of fowl plasma and chicken embryo extract. Some development and growth of wool follicles have been observed.

(iii) *Growth of Marsupial Skin and Hair in vivo and in vitro.*—Because the young of marsupials are born at an immature stage, and because the structure and development of their skin and hair are fundamentally similar to those of placental mammals, they are extremely suitable animals for studying many of the problems of the biology of skin and hair. The methods used to grow sheep skin and wool in tissue culture have been applied at regular intervals to the skin of two pouch young of the brush possum (*Trichosurus vulpecula*). This study is in progress.

(iv) *The Expression of the Gene "Tabby" in the Hair of the Mouse.*—This work is still in progress. The gene *Ta* causes absence of two of the three types of pelage hair follicles and a reduction in the number of facial vibrissae in the supra-orbital, post-orbital, post-oral, and interramal regions. The present hypothesis is that the gene acts directly on the skin by suppressing the initiation of hair follicles, and the times when the action begins and ends were accurately defined from observations made on vibrissae and pelage hairs.

(v) *Effect of Oestrogens on Vaginal Epithelium in Tissue Culture.*—The mode of action of oestrogens is being investigated from several aspects by Dr. J. D. Biggers and Mr. P. Claringbold of the Department of Veterinary Physiology, University of Sydney. In collaboration with these workers, a study was made of the action of oestrogens in tissue culture. Pieces of the vaginal wall of immature mice were cultivated for three or four days in a mixture of capon plasma, chicken embryo extract, and a solution containing an oestrogenic substance. Each of the twelve oestrogens tested produced a typical stratification, and sometimes keratinization, of the vaginal epithelium, while control explants without oestrogen retained a simple epithelium. The dose-response relationship for oestrone has been investigated. The effective dose for oestrone in tissue culture was only about 1 per cent. of the effective dose when the same substance was administered intravaginally to the intact animal.

(*d*) *Skin and Fleece Development.*—(i) Further observations on competition between skin follicles in sheep have shown that competition between secondary follicles, and between secondary and primary follicles, is complicated by competition between primary follicles. This latter effect is therefore being studied in early foetal material.

(ii) Preliminary investigations are in progress on the effect of the plane of nutrition during pregnancy on the development of the skin follicle population.

(iii) Earlier examinations have shown that a large number of undifferentiated secondary follicles is present in the skin of the lamb at birth. Recent observations indicate that there is close agreement between the total secondary follicles in all stages present at birth and the number of follicles which are subsequently found to mature in early post-natal life. This suggests that the potential secondary population is determinable during pre-natal life. Other observations indicate that the number which actually become fibre-producing follicles is conditioned by post-natal conditions.

(iv) Observations on two Merino sheep which showed a low ratio (7 : 1) of secondary to primary follicles at maturity indicated that these animals had a normal potential follicle population at birth, but that a large proportion of the secondary follicles failed to progress to the mature phase of fibre production. Outwardly these animals appear to be quite normal except for the production of a Down type fleece.

(*e*) *Physical Studies of wool.*—(i) *Maximum Conditioning Speeds.*—The maximum speed at which wool fibres could be conditioned to equilibrium with a new atmosphere has been determined. The basis of the method is that the regain changes are made to occur in air streams so rapidly that the temperature of the fibre and the humidity at its surface differ negligibly from those of the main air stream. As an example of the results, it was found that at room temperature (about 25° C.), when absorbing from the dry state (regain = 0 per cent.) in an atmosphere that gave a final equilibrium of 19 per cent. regain, one-half of the total change took place in 20 sec., and three-quarters of the total change in 40 sec. By contrast, when desorbing from 19 per cent. regain towards the dry state, one-half of the total change was completed in the first 20 sec. as in adsorption but three-quarters of the water was not lost until 200 sec. had passed.

(ii) *Diffusion of Water in Wool Fibres.*—The general case of a variable diffusion coefficient, and calculation of the regain *v.* time curves for desorption in dry air from 19.2 per cent. regain and for absorption from the dry state to 19.2 per cent. regain, has been explored. Desorption was slightly faster than was to be expected from King's data for horn, and absorption very much slower than expected. The explanation advanced is that, as has been suggested for some other high polymers, there is a time lag in the adjustment of the diffusion to a change in regain.

(iii) *Specific Heat of Wool.*—In attempting to elucidate anomalous results in the heat transfer experiments, the value for the specific heat of wool was reconsidered. The original value for the specific heat of sheep's wool was confirmed, but some modifications were found necessary in the method of measurement as originally described.

(iv) *The "Handle" of Fleece Wool.*—The analysis of the second "handle" experiment, described in the last Report, confirmed the finding that diameter differences were the major cause of variations in handle, and that depth of crimp was also a contributing factor. The finding that increasing the percentage of suint caused a deterioration in handle was not confirmed. Additional significant factors in the second experiment were the coefficient of variation in diameter (1 per cent. level) and the staple length (5 per cent. level). The dependence of handle on the various characters was such that diameter differences could cause as much as 3.6 grades difference in handle (maximum difference of five grades), whereas the maximum effects ascribable to the other significant characters were between 0.5 and 1.0 grades. The inherent stiffness of the fibre (as indicated by measurements of Young's modulus) was not quite significant as a factor determining handle, and even if it were the regression coefficient indicates that only about 0.5 grade difference could be caused by it.

(*f*) *Routine Measurements.*—(i) *Histological Examinations.*—A total of 1800 sections have been processed during the year. Of these, approximately 90 per cent. were from sheep for routine follicle counts and fibre diameter measurements; 5 per cent. were from cattle skin; and 5 per cent. from miscellaneous post-mortems.

(ii) *Physical Measurements of Fleece.*—During the year, 27,237 measurements were made on fleece samples, including determinations for yield, density, mean diameter, staple length, and crimp. Most of these measurements were made for projects within the Division, but some 15 per cent. were for other projects. The storage of samples was placed on a permanent basis.

17. SHEEP DISEASES.

(Division of Animal Health and Production.)

(*a*) *Caseous Lymphadenitis of Sheep.*—The preliminary test of the efficacy of vaccination with *Corynebacterium equi* against infection with *C. ovis* was concluded. The intradermal route of inoculation had shown promise as a means of artificially inducing the disease. The strain used to challenge the immunity of the vaccinated sheep had unfortunately lost its virulence and the results were inconclusive.

The field experiments in New South Wales designed to determine the value of two possible methods of control of the disease have now been concluded. One method was an annual pre-shearing vaccination and the other the placing of the sheep directly "off-shears" in a clean rested paddock. The experiment was commenced in 1946, when two groups of young wethers were submitted to one or other of the methods, which were repeated each year until the animals were sent for slaughter. Further groups of wether weaners were brought into the experiment in 1947, 1948, and 1949. The last groups were slaughtered and examined in 1954. In earlier groups vaccination seemed to have reduced the incidence of infection by about half. However, groups slaughtered in 1952 and 1954, which had come into the trial in 1948 and 1949, showed little benefit from the vaccine used or from the use of a clean rested paddock for newly shorn sheep.

(*b*) *"Toxaemic Jaundice" of Sheep.*—This co-operative investigation has been continued at the Animal Health Research Laboratory, Melbourne. Investigation of natural outbreaks, which have been few during the year, has been continued in co-operation with the veterinary research staff of the New South Wales Department of Agriculture. Further observations have been made on losses in sheep due to uncomplicated chronic copper poisoning and to straightforward heliotrope poisoning.

In addition, further confirmation of the increased susceptibility to chronic copper poisoning of sheep which have grazed on heliotrope has been obtained, and there is some evidence that susceptibility to the haemolytic crisis of chronic copper poisoning may also result from grazing on some plants other than heliotrope. The investigations have progressed along the following lines.

(i) *Chronic Copper Poisoning.*—In the field experiment at Tumbarumba, New South Wales, no molybdenum was included in the superphosphate with which the pastures were top-dressed this year, and the experiment was continued to determine the residual effects of the previous year's molybdenum application on copper storage in the livers of the sheep and the protection provided by this treatment against chronic copper poisoning. For the third successive year the season was unfavorable to the occurrence of the disease. The observations showed, however, that the pastures contained 6-8 p.p.m. of molybdenum, compared with 0.2 p.p.m. in the control, and that while the copper concentration in the liver of the sheep grazing the pasture on the control plots remained approximately unchanged during the year, in the sheep grazing the pasture which had been top-dressed with superphosphate containing molybdenum at the rate of 8 oz. molybdenum/acre during the autumn of the previous year the liver copper concentration had been reduced from 450 to 180 p.p.m.

Laboratory studies of the factors influencing the storage of copper in the liver have been continued. These studies are in progress and results indicate that the smaller the amount of molybdenum in the diet the greater is the amount of sulphate required to prevent copper accumulation, and conversely, the smaller the amount of sulphate the greater is the amount of molybdenum required.

It has been demonstrated experimentally in crossbred sheep that, provided the diet provides a certain minimal amount of inorganic sulphate, excessive intakes of molybdenum, of the order of 100mg/day, may result in fleece lesions similar to those observed under conditions of copper deficiency including banding of the fleece in black sheep.

Other experiments, designed to elucidate the mechanism of the action of molybdenum and inorganic sulphate on the copper metabolism of the sheep, have demonstrated that the level of copper in the circulating blood is elevated when the intake of both molybdenum and sulphate is high, but not when either alone is at a high level. The significance of the effects are being studied in current experiments.

(ii) *Heliotrope Poisoning.*—Sufficient quantities of three of the alkaloids of *Heliotropium europaeum* and of their *N*-oxides have now been prepared by officers of the Division of Industrial Chemistry to enable extensive studies on their toxicology and pathological effects in small animals to be undertaken. These studies are proceeding. A start has been made in assaying the alkaloid content of the plant at several stages of growth and of plants growing under different climatic conditions.

(*c*) *Sheath Rot of Wethers.*—In studies in the Western District of Victoria, seventeen of twenty wethers from a mob, in which two-thirds of the animals were exhibiting external ulcers and 1-2 per cent. internal lesions of the sheath, were free of lesions after grazing for three weeks on a cape-weed-*Cryptostemma calendulaceum*-dominant pasture, and eighteen of another twenty were free of lesions after a diet of oaten chaff for three weeks. The incidence of sheath rot did not change during this period in animals which were grazed in the original paddock. Subsequently the treatments were reversed. Most of the animals in which the lesions had disappeared on the cape-weed-dominant pasture or on the diet of oaten chaff, exhibited lesions again three weeks after they had been returned to the original pasture containing subterranean clover as well as ryegrass. In the same period the lesions had disappeared from all, or almost all, of the animals which had been transferred from the grass pasture to the cape-weed-dominant pasture or to the diet of oaten chaff. The lesions had also disappeared from eleven of twenty animals after they had grazed on a crop of green oats for two weeks but re-appeared after further grazing on this crop.

The animals on the cape-weed-dominant pasture gained weight and those on the diet of oaten chaff lost or barely maintained weight during the period in which the lesions disappeared. The urine of the animals on the cape-weed-dominant pasture was significantly more alkaline in reaction than the urine of the animals on the grass pasture in which the incidence of lesions had not changed.

(*d*) *Footrot in Sheep* (*MacMaster Laboratory*).—The sensitivity of *Fusiformis nodosus* to the common antibiotics was tested. It was found that striking results were obtained with 10 per cent. cloromycetin in propylene glycol or in methylated spirits. Penicillin might be equally efficient but its instability is a disadvantage in field use. In field trials on three properties, using 10 per cent. chloromycetin in methylated spirits, 87 per cent. of 107 affected feet were cured by one treatment and 100 per cent. by two treatments. Lower concentrations of chloromycetin resulted in much lower efficiency. With the co-operation of the State Departments of Agriculture and the Commonwealth Department of Health, eleven trials of the efficiency of this form of treatment were conducted on a total of 700 affected feet. One or two treatments resulted in the cure of 93 per cent. of the affected feet.

A conference on footrot, between officers of the Organization and of the State Departments of Agriculture, was held at Young, New South Wales, in August.

(*e*) *Epididymitis in Rams—Ovine Brucellosis.*—Investigation of this condition has been confined to the bacteriological examination of some cases. A conference of research workers who are investigating this disease in the several States, was convened by the Organization in Adelaide in December. Information was exchanged and plans for further investigations were formulated. Ovine brucellosis is not a problem on which the Division is actively engaged at present.

18. INTERNAL PARASITES.

(Division of Animal Health and Production.)

(*a*) *Anthelmintics* — (i) *Phenothiazine.* — Further studies were made on the relationship between particle size and the anthelmintic efficiency of phenothiazine against *Haemonchus contortus, Oesophagostomum columbianum,* and *Trichostrongylus* spp. In a series of trials it appeared that anthelmintic efficiency was satisfactory provided about 90 per cent. of particles were less than 30μ in diameter. Phenothiazine appeared to be less effective against *Ostertagia* spp. than against *T. colubriformis.* In the field, monthly drenching with phenothiazine, in a flock in which the worm burden was low, slightly reduced weight gains and aggravated photosensitization of the ears. In worm-free penned sheep drenching with phenothiazine resulted in a reduced appetite for some days.

(ii) *Mode of Action of Phenothiazine and Related Compounds.*—These compounds are being synthesized and their chemical and chemico-physical properties studied at the Department of Chemistry, University of Sydney; their anthelmintic efficiency is being tested against *Syphacia* spp. in mice at the McMaster Laboratory.

The compounds which showed anthelmintic efficiency were: 1-methoxyphenothiazine, 3-ethoxyphenothiazine, 4,4-dichlorodiphenylamine, and 1,8-dihydroxyanthraquinone. Those which failed to show more than slight anthelmintic effects were: 3-phenylphenothiazine, 3-iodophenothiazine, *N*-benzoylphenothiazine, and 2,4-dinitrodiphenylamine. Efforts made to prepare *p.p*-dichlorophenothiazine have not yet met with success. Further tests with phenothiazine of different particle sizes against *Syphacia* spp. in mice have not yet yielded decisive results.

(*b*) *Resistance to Nematode Parasites.*—Observations were continued at Armidale on the effect of anthelmintic treatment on the resistance of sheep to *Trichostrongylus* spp. The observation that elimination or reduction of *Trichostrongylus* spp. infestations in weaners and lambs did not significantly impair their ability to resist a fresh challenge infestation was confirmed.

A series of experiments has been conducted at the McMaster Laboratory throughout the year in an attempt to elucidate the relationships between intake of infective larvae of *T. colubriformis* and the development of resistance by the sheep. It was shown that sheep which were resistant to *T. colubriformis* were susceptible to *T. axei* but resistant to *T. vitrinus.* Sheep which were resistant to *T. axei* were usually susceptible to *T. colubriformis.* The antibody response to *T. axei* commenced about one month after infestation and accorded with that which occurs in infestations with *T. colubriformis.*

It appears that the intake of larvae of *H. contortus, T. axei,* and *Ostertagia* spp. will produce "self cure" of infestations with the adults of each species.

(i) *The Effect of Infestation with* T. colubriformis *on the Blood Level of Vitamin A.*—Some penned lambs harbouring heavy infestations with *T. colubriformis* showed unusually low levels of vitamin A in the blood. However, sheep in the field infested with *T. colubriformis* showed no benefit from a dose of a commercial preparation of vitamins A and D.

(ii) *Food Intake and Faecal Output.*—Observations on lambs kept in single pens demonstrated a close correlation between faecal output and food intake. The finding may be of assistance in assessing effects of worm infestations on appetite.

(iii) *Oesophagostomosis and Grazing Oats.*—In sheep grazing on oats at the McMaster Field Station there was a close relationship between the elimination of *Oe. columbianum* and *Trichuris ovis* and a reduction in the pH of the faeces. This apparent relationship had previously been observed at the Regional Pastoral Laboratory, Armidale. Most of the worms were passed when the pH of the faeces had fallen to less than 6.5.

(iv) *The Control of Fascioliasis.*—Field observations on the efficiency of molluscicides were continued in the Oberon district. Copper pentachlorophenate applied as a 10 per cent. dust at a rate of 10-15 lb./acre appeared to be highly efficient for the destruction of *Simlimnaea subaquatalis.* Trials were held in co-operation with the New South Wales Department of Agriculture, Timbrol Ltd., and Grazcos Pty. Ltd.

Methods are being developed to maintain *S. subaquatalis* in colonies in the laboratory and thus provide material for future study.

(v) *Distribution of Nematodes in the Alimentary Canal of the Sheep.*—The distribution of *T. axei* in the abomasum was studied 96 hr. after the oral administration of larvae. Larvae were located in all parts of the mucosa, although more were found on the outer edges of the spiral folds than elsewhere. It is known that *H. contortus* larvae invade the mucosa 12-40 hr. after oral infestation. In sheep killed 25-30 hr. after oral infestation numerous larvae were present in the mucosa of the mid region of the abomasum, decreasing in numbers toward the pyloric and cardiac regions.

It is known that the parasites which inhabit the small intestines of sheep and rabbits tend to be located in the form of a normal frequency distribution. It was found that this also applies to worm parasites of cattle. It was shown that parasites in an abnormal host (e.g. *T. colubriformis* in rabbits and *Cooperia oncophora* in sheep) also follow a normal frequency distribution. The location of different genera of species in the intestine tends to be the same in all these animals and hence the factors responsible for localization may well be similar.

(vi) *The Histology of the Ovine Abomasal Mucosa.*—The distribution of the peptic and parietal cells were mapped, but difficulty was experienced initially in staining the argentaffin cells. Golgi's chrom-silver stain was used in a study of a hitherto unrecognized type of cell in the sheep's abomasum. Attention was given to the incidence of the "Schollenleukozyten" or globule leucocyte, the significance of which is unknown. It was usually found in the mucous membrane of the abomasum or intestines of sheep which were infested for at least 5 weeks, but was absent in the mucosa of worm-free lambs. Its presence was not related to the immune state of the host.

(*c*) *Epidemiological Investigations.*—During the past year, the dry season in New South Wales resulted in worm burdens being generally very light. In the Yass district, sheep drenched monthly with phenothiazine had lighter infestations than control sheep, but did not gain more weight. In one of the trials 10 sheep were selected each month and their resistance was tested by administering *T. colubriformis* larvae. The sheep were highly susceptible in January and February but less so in March.

At Deniliquin, observations were made on worm egg counts, worm counts, and body weights of autumn 1953 drop lambs. Lambs on irrigated pastures gained weight steadily from the end of June, 1953, to the middle of January, 1954, but at a lower rate than those grazing non-irrigated native pastures. The lambs on native pasture gained steadily until mid-November but thereafter very slowly up to shearing at the end of February. There was a difference of 5.0 kg. between the average weight of the groups at the end of November and 2.6 kg. in February. The lambs on irrigated pastures cut an average of 6.95 lb. wool and those on native pastures 7.2 lb.

Worm infestation increased from July and declined from the end of November. In the lambs on irrigated pastures the egg counts reached 1800-2000 per g. of faeces in early September, whereas those from the sheep on natural pastures never exceeded 500-600. The early increase in faecal count was due to *Trichostrongylus* spp. and *Nematodirus* spp. whereas *Ostertagia* spp. and *T. axei* reached their maximum development in November.

Observations on ewes in Tasmania showed increases in worm burdens during the lambing period in the spring months. This resulted in a fourfold increase in the daily contamination rate of pastures and emphasized the need for treating the ewes prior to lambing. The faecal egg counts and the worm infestation of spring lambs at the Cressy Experiment Farm reached their peak in mid December and then declined in early January. At this time the lambs were weaned and worm egg counts increased rapidly. These trends were also shown by lambs in other epidemiology trials in Tasmania and indicate the need for treatment about the end of January. Each month five lambs or weaners were given a dose of 50,000 *T. colubriformis* larvae. No resistance was apparent during October and November, but some what lighter infestations resulted in December. However, in January and February the test sheep appeared to be fully susceptible.

The epidemiological studies were continued in Western Australia and an additional trial was commenced at Bridgetown. Heavy rain in the autumn of 1953 was probably responsible for infestations in the spring being up to 10 times greater than at the same time in the previous year. In the trial at Beverley a group of sheep drenched four times with phenothiazine cut an average of 1.4 lb. more wool than the controls. In another trial there was only a slight difference in wool weights but 70 per cent. of the control fleeces showed a "break". The outstanding features of these trials were high infestations with *H. contortus* at Bejoording in spring and midsummer heavy infestations with *Trichostrongylus* spp. in early summer at Kojonup and Cranbrook, and the early increase of *Chabertia ovina* in midsummer at Cranbrook.

Studies on the seasonal changes of infestations with *Nematodirus* spp. were carried out in the Northern Tablelands of New South Wales. Peak infestations were reached in August-September and in January, February, and March, with pronounced troughs in October-November and April-May. On seven properties in Western Australia, the peaks were reached in September-November and February-March, with troughs in the early summer months and in the autumn.

The investigations at Armidale in which the fluctuations and levels of worm burden in sheep grazing sown and native pasture were compared have been concluded by a series of post-mortem examinations of sheep from each group. These autopsies have confirmed the high level of *Oesophagostomum columbianum* infestation in sheep grazing native pasture. The number of nodules in the bowel wall was also considerably greater. However, when sheep from the sown pasture group were drenched with infective *Oe. columbianum* larvae they developed many nodules. Observations are being continued.

Complementary studies of the factors which, under field conditions, are associated with the lower worm burden of sheep grazing sown pasture are continuing, with particular reference to the level of nutrition and the availability and level of intake of infective larvae.

In association with the studies on the ecology of parasitic larvae, worm-free lambs were used to obtain a qualitative measure of the larvae available on sown and native pastures. This information is also being correlated with the epidemiological observations.

Observations have also been made on the effect of the level of nutrition and of an existing adult population of *Oe. columbianum* on the emergence and establishment of fourth stage larvae.

(*d*) *Bionomics of Free-living Stages of Nematodes of Sheep.*—Studies on the ecology of nematode larvae have been continued at the Regional Pastoral Laboratory, Armidale, New South Wales, by an Ian McMaster Scholar.

The temperature and moisture requirements of the free-living stages of *Haemonchus contortus, Oesophagostomum columbianum, Trichostrongylus* spp., and *Nematodirus* spp. have been examined experimentally. Temperatures are suitable for the development of infective larvae of *H. contortus* and *Oe. columbianum* on pasture in New England from October to April, but during the remainder of the year eggs do not remain viable. Large numbers of infective larvae only develop when the pellets are continuously moist, and this is governed by the distribution and amount of rainfall, evaporation, and density of pasture cover. The lower temperatures at which *Trichostrongylus* larvae develop, together with the extreme resistance of the embryonated egg to desiccation, results in the accumulation of viable eggs during a dry autumn period and in mass hatching in the late autumn and early winter in New England.

(*e*) *Parasite Survey.*—From a large number of autopsies on sheep carried out at Armidale, no new species of parasite has been recorded but *Trichostrongylus axei* has been found to occur commonly and often in large numbers.

From the survey of parasites of foxes the occurrence of the cold climate hookworm *Uncinaria stenocephala* and the roundworm *Toxocara canis* are recorded.

(i) *Parasite Physiology and Toxicology.*—Research on the biological activity of complex ions was continued in collaboration with the Chemistry Department of the University of Sydney.

Earlier experiments showed that the cationic complexes were reversible competitive inhibitors of acetylcholine esterase (Ach E), whereas the uncharged complexes were without action. It was decided to investigate further the effect of charge on the inhibition of Ach E. The charge and charge distribution on the complexes is determined by the electronegativity of the central metal atom, by the electrophyllic properties of the ligands, and by the size of the whole cation. Therefore, by altering any one of these factors, complexes with different peripheral charges can be contrived. The ideal substances to investigate the charge-dependence of inhibition would be a series of complexes in which the members differed from each other only in a single property, but this can only be approximated.

The first group tested consisted of Co complexes carrying three, two, one, and no positive charges. The zero charge had no effect, but otherwise this series did not give much additional information.

The second group consisted of $Ru(o\text{-phen})_3(ClO_4)_2$ complexes, having at the five-position on the phenanthroline different electron-attracting or -repelling groups. Here again the sizes of the members vary.

The third group consisted of three series, viz. $Me(phenanthroline)_3(ClO_4)_2$, $Me(dipyridyl)_3(ClO_4)_2$, and $Me(terpyridyl)_2(ClO_4)_2$.

The members of these series contained only different central metal atoms, the rest of the ions being identical. Therefore the charge on these cations varied from one member to the other only in accordance with the different electron negativities of the central metal atoms, and with the difference in the sizes of the metal atoms, which is negligible.

The results with these last two groups showed that the inhibition caused by the complex cations depended on their charge; the greater the positive charge on the surface, the stronger the inhibition of the enzyme. Among the 30 complex ions tested there were three whose action was not quite as expected. Solubility measurements are being made in an effort to disclose the reason for this.

The toxicity of the compounds was tested by LD50 determinations on mice and showed the same trend as their enzyme-inhibiting activity. These experiments were done with racemate forms of the complexes.

The experiments with $^{104}Ru(o\text{-phen})_3(ClO_4)_2$ were continued. It was found that the difference in the toxicities of the *d*- and *l*-forms after intraperitoneal injections was caused by their different ability to permeate tissues. The *d*-form was found in higher concentrations both in serum and urine.

Experiments with intraperitoneal injections of *d*- and *l*- forms of $^{104}Ru(o\text{-phen})_3(ClO_4)_2$ were done. It was found that the bulk of the injected material was excreted unchanged within a short time in the urine. Apart from blood and urine only kidney, liver, and pancreas contained significant amounts of the complex.

It was found earlier in toxicity experiments that a non-lethal amount of the less toxic *l*-form of a complex rendered a subsequent lethal dose of the *d*-form ineffective. This experiment was repeated by injecting intra-peritoneally the non-radioactive *l*-form prior to the radioactive *d*-form, and the appearance of the radioactive material in the blood stream was followed. Even at different dose rates lower levels of *d*-forms were found in the blood stream than in the control animals which received the same amount of *d*-form only. It was concluded that the *l*-form of the complex inhibited the penetration of the *d*-form.

It was found previously that after the intraperitoneal injection of different charged complexes the urine of the animals contained considerable amounts of reducing substances. On examining the behaviour of blood glucose levels after the injection, a curve was obtained which was identical with the blood glucose behaviour after $CoCl_2$ injection. It is generally believed that $CoCl_2$ causes rise of blood glucose by exciting the α-cells of the pancreas. These cells disappear 24-48 hours after $CoCl_2$ injection. The results indicated that both $CoCl_2$ and the complexes tested can elicit a rise in blood glucose levels at a time when α-calls are no longer demonstratable and that the α-cells disappear after $CoCl_2$ injection, but not after the injection of the complexes. Injection of $CoCl_2$ together with different amino acids did not inhibit the glucose response but two of them, methionine and histidine, prevented the damage to α-cells. It was concluded that the glucose response is not directly related to disappearance of α-cells, which is merely coincidental.

19. EXTERNAL PARASITES.

(Division of Animal Health and Production.)

(*a*) *Ecology of Ectoparasites.*—*Damalinia ovis* has been studied chiefly, with particular reference to the effect of temperature on its ecology. It was shown that the distribution of eggs of *D. ovis* in the fleece was determined by the temperature prevailing within the fleece. Lice placed on glass wool and exposed to a temperature gradient laid their eggs between 39° and 36° C., which coincides with the range existing in the fleece. Lice migrate to the warmer region suddenly about 45 min. before oviposition. At first the louse places its head in the warmer region but reverses its position 5 min. before oviposition and places the posterior tip of the abdomen in the warmer region. Oviposition occupies some 30 sec., after which the louse returns to the cooler area. *Linognathus* *stenopsis* behaved similarly in a goat. When the temperature was equalized throughout a fleece, *D. ovis* oviposited along the whole length of the wool fibre.

Furthter observations confirmed that the preferred site of *Linognathus ovillus* is the face. It spreads from this area over the ventral aspect of the neck and is brushed on the body. Complete control of this parasite was obtained in a trial with benzene hexachloride at the concentration employed for the control of *D. ovis.*

Studies on the life cycle of *Psorergates ovis* were continued and, although the previously reported findings were confirmed, it has not yet been possible to determine the exact length of the life cycle.

20. PROTECTION AGAINST BLOWFLY STRIKE.

(Division of Animal Health and Production.)

Investigations have continued at Yeerongpilly, in co-operation with the Queensland Department of Agriculture and Stock, on the value of various insecticides applied to the fleece to protect sheep against sheep blowflies, and have been extended to include systematic administration of insecticides.

(*a*) *Body Strike.*—The protection given by spraying or jetting DDT, BHC, aldrin, dieldrin, and malathon was determined by applying the insecticide to the dorsal areas and then exposing the treated animals to a heavy population of gravid *Lucilia cuprina* in an insectary with indole plugs inserted into the fleece as an attractant. The anti-larval protection was tested by placing newly hatched maggots of this blowfly on the skin of the treated areas at various intervals after treatment.

It was quickly determined that jetting gave significantly greater protection against both adults and larvae than spraying. As an anti-adult insecticide DDT (1 per cent.) proved more lasting than BHC, aldrin, or dieldrin (0.25 per cent. active ingredient). Further tests of the anti-adult properties of BHC, aldrin, dieldrin, and malathon, at 0.25 and 0.1 per cent. active ingredients, showed that BHC at the higher concentration gave considerable protection at five weeks, whereas with the other insecticides protection at this period was poor. Against larvae, in one trial aldrin (0.25 per cent.) gave good protection for 23 weeks, dieldrin (0.25 per cent.) for seventeen weeks, BHC (0.25 per cent. gamma isomer) for eighteen weeks, and DDT (1 per cent.) for only eight weeks. Another trial which included malathon (0.05-0.25 per cent.) showed this insecticide to be much less effective than BHC, aldrin, and dieldrin at similar concentrations. In this trial BHC was less effective than aldrin and dieldrin, which were about equal, giving 17-18 weeks' protection at a concentration of 0.25 per cent. Field trials were carried out with aldrin, dieldrin, and BHC, but unfortunately flies remained inactive.

(*b*) *Head Strike in Rams.*—A field trial was carried out with 1 per cent. dieldrin jetted into the area at the base of the horns. During the eleven weeks after treatment, twelve strikes had occurred in 111 control rams, whereas none of the 568 treated rams had been struck.

(*c*) *Treatment of Strike.*—Preliminary observations have been made on the treatment of artificial strikes by jetting the struck area and surrounding wool with aldrin, dieldrin (0.05-0.2 per cent.), and BHC (0.05-0.2 per cent. gamma isomer). In all instances the struck areas were free of maggots within 24 hours of treatment, healed quickly, and at the highest concentrations remained resistant to implants of larvae for up to thirteen weeks.

(*d*) *Systematic Administration of Insecticides.*—In preliminary work aldrin in peanut oil was administered subcutaneously to guinea-pigs and sheep. At intervals after administration, the blood was tested by a bioassay method against newly hatched maggots of *L. cuprina.*

Blood from guinea-pigs 2 hr. after dose rates of up to 20 mg./kg. of body weight was non-toxic to maggots, but when the dose rate was raised to 35 mg./kg. body weight none of the maggots survived.

Two sheep remained unaffected at dose rates of 50 and 100 mg./kg. body weight and their blood at intervals of 2, 4, 6, and 24 hr. after treatment was not toxic to maggots. These investigations are proceeding.

21. OTHER INVESTIGATIONS.

(Division of Animal Health and Production.)

(*a*) *Neo-natal Mortality in Lambs.*—At Armidale in 1951, ewes of several Merino strains, mated and lambed under pen conditions, reared a higher percentage of lambs than station ewes mated and lambed under paddock conditions. Under pen conditions there was a higher percentage of ewes lambing and a lower death-rate in the lambs.

A study was commenced of the effects of different husbandry practices at mating and lambing on the percentages of the ewes lambing as well as on lamb mortality. Merino ewes of all ages were used. The husbandry practices were described in the last Report. In 1953, these observations were continued and an "unattended" paddock system was also included. In this system attention was restricted to cast ewes and ewes unable to lamb.

There was an average mortality over all treatments of 14 per cent. The greatest loss occurred within the first three days of life and only a small proportion had suckled before death.

Mortality in lambs ranged from 9 per cent. in the group lambed later off shears, and 10 per cent. in the group lambed later in the wool, to 11 per cent. in the modified paddock system, 12 per cent. in the pen lambings, and 18 and 20 per cent. in station paddock "attended" and "unattended" systems respectively.

(*b*) *Production of Native Pastures used in Conjunction with Sown Pastures.*—In co-operation with the Division of Plant Industry (*see* Chapter III., Section 18), a study is being made of the animal and pasture production from land units composed of increasing proportions of sown pasture (3.9, 15.5, 30.8, and 57.1 per cent.), using a composite flock of breeding ewes, weaners, and wethers. In the first year, 1953, animal and pasture production increased in relation to the amount of sown pasture available. The liveweight gain of 42 lb. and wool production of 20 lb./acre where 57.1 per cent. of sown pasture was available was more than double the production with only 3.9 per cent. sown pasture.

VIII. CATTLE.

1. GENERAL.

Products of the cattle industry—meat, hides, and dairy produce—represent over 20 per cent. of all Australian rural production. With the rapid increase in the population of Australia in the post-war period, home consumption of food commodities is outstripping primary production. If Australia is to maintain both its own food standards and an export of meat and dairy products on the pre-war level, research must find the means to increase the entire cattle industry.

Broadly, the approach of the Organization to the problem of the cattle industry comprises:—

(i) A survey of the structure and interrelations of the various sections of the beef cattle industry throughout Australia.

(ii) Studies designed to eliminate wastage and loss from disease in both beef and dairy cattle.

(iii) The exploitation of potentialities for improving nutrition by the development of sown pastures; scientific understanding of the characteristics and management of natural pasture and study of the possibility of introducing desirable exotic species into natural pastures.

(iv) The development of systems of breeding designed to evolve more productive beef and dairy types for north Australian conditions.

The Organiaztion's work on cattle problems has been carried out chiefly by the Division of Animal Health and Production, mainly in the Animal Health Laboratory in Melbourne, the National Cattle Breeding Station at "Belmont", near Rockhampton, Queensland, and the Veterinary Parasitology Laboratory in Brisbane, Queensland (*see* Sections 2, 3, 5, 6, and 7 (*b*) of this Chapter). The Division of Entomology has been concerned with work on the cattle tick (*see* Section 4 of this Chapter). The work of the Division of Plant Industry on pastures is also of great importance to the cattle industry (*see* Chapter III.). The work of the Animal Genetics Section on beef cattle is described in Section 7 (*a*) of this Chapter.

2. Cattle Diseases.

(Division of Animal Health and Production.)

(*a*) *Pleuropneumonia of Cattle.*—Further work has confirmed the earlier finding that attempts at vaccinating very young calves are likely to lead to losses associated with painful joint infections and valvular lesions in the heart. These complications are directly related to the age at which tail vaccination is carried out. Of 32 calves vaccinated when seven days old, thirteen (41 per cent.) developed swollen joints (carpal and/or tarsal), and four (12 per cent.) specific valvulitis; of 30 vaccinated when 20 to 30 days old, eight (27 per cent.) developed swollen joints and two (7 per cent.) heart lesions; of 30 vaccinated when 40 to 50 days old, one (3 per cent.) developed swollen joints and none heart lesions; and of 30 vaccinated when five to seven months old, none developed swollen joints or heart lesions. The vaccinated groups are yet to be tested for immunity.

The first recorded instance of tonsillar infection with the pleuropneumonia organism occurred in the mother of one of the calves vaccinated seven days after birth. The mother developed a positive complement-fixation reaction eleven days later, but no other signs of infection. At autopsy no abnormalities were found. The organism was recovered from both tonsils, but from no other site. This experience suggests that tonsillar infection may be a cause of no-lesion complement-fixation reactions, or of transient reactions which have been observed during an epidemic. Much attention is being given to a study of the nutritional requirements of the causal organism, in particular to the nature of the serum factor or factors. Indications are that serum supplies substances other than cholesterol.

A film dealing with the problem of pleuropneumonia in Australia, and with the contributions made by the Organization, was prepared by the Film Unit with the assistance of the Animal Health Laboratory, Melbourne. The film is designed for the use of research workers and disease control authorities, and has been well received by them.

During the year 499,450 doses of vaccine were distributed. Sufficient complement-fixing antigen was supplied without charge to laboratories within Australia to test 42,200 animals, and abroad (Kenya, Spain, Japan) to test 15,700 animals. In addition sufficient concentrated stained antigen was supplied to Queensland to test 3,000 animals by the rapid whole-blood slide agglutination test.

(*b*) *Mastitis in Dairy Cattle.*—Further therapeutic trials with antibiotics were carried out against staphylococcal mastitis, using the same criterion of bacteriological cure referred to in earlier Reports. The agents investigated were chloromycetin, penicillin combined with the surfactant "Manoxol", and penicillin combined with hyaluronidase; but in no case was the infection eliminated from any of the quarters. Work has been carried out on the correlation of laboratory tests (coagulase, haemolysin phosphatase) with pathogenicity of staphylococci.

(*c*) *Brucellosis in Cattle.*—In Australia and elsewhere heavy economic losses due to abortion have been considerably reduced by protective vaccination with *Brucella abortus*, strain 19—a method that was first introduced in the United States of America. In earlier investigations of the degree and duration of the protection afforded vaccinated cattle, the results of experiments performed at the Animal Health Laboratory, Melbourne, agreed with those of workers overseas as to the high degree of resistance to abortion but differed in revealing a high infection rate in those cattle which did not abort. In the Australian experiments larger groups of cattle were used than in overseas work and further tests abroad have now confirmed the Australian results.

The findings of previous years on the duration of immunity under severe and repeated challenge indicated that the great majority of cows which completely resisted infection at the first challenge continued to do so when their immunity was challenged in subsequent years. The tests have been continued for another year. Each of two groups of about 20 animals had reached the fifth year after calfhood vaccination but one group had been revaccinated with strain 19, three years after calfhood vaccination. Together with a third, or control, group of seventeen animals, the vaccinated groups were subjected to the hazard of infection under conditions closely simulating those in the field. The infection rate in the control group was 76 per cent. and the abortion rate 53 per cent., whereas the infection rate was zero in the once-vaccinated group and 4.8 per cent. in the twice-vaccinated, with no vaccinated cattle aborting. The difference between the vaccinated groups was not statistically significant and the cumulative results of tests on the duration of immunity indicate a very useful resistance, continuing into the fifth year after calfhood vaccination with no advantage evident as a result of revaccination. Tests are being continued. These field tests have supplied valuable material for important academic studies on *Br. abortus* and its pathogenicity.

(*d*) *Haematuria Vesticalis of Cattle.*—The work referred to in the previous Report was continued; tissues from the surviving mice have been prepared for examination. Another small area in which the disease is said to have been endemic for up to twenty years came under notice and was visited. It is of particular interest because, unlike haematuria areas previously visited in Victoria and South Australia, there was no suggestion of earlier volcanic action; indeed, the general geography was very similar to that described for affected areas in Germany and Transylvania. The area was surveyed by scintillograph by the Victorian Mines Department, but the level of gamma radiation was not above normal.

(*e*) *Infertility in Dairy Cows.*—An outbreak of an acute and readily transmissible vaginitis has been investigated. It has not been transmitted by filtrates, but none of the demonstrable bacteria isolated is able to reproduce the disease. Treatment of infective material with antibiotics, in an attempt to characterize the causal agent, has given irregular results.

3. Internal Parasites.

(Division of Animal Health and Production.)

The following investigations have been carried out by the staff of the Veterinary Parasitology Laboratory, Queensland.

(*a*) *Epidemiology of Parasitis Gastro-enteritis of Cattle.*—(i) *Seasonal Trends in Helminth Populations.*—Observations have been continued on herds at Dayboro and Goodna, Queensland. The trends given by the egg counts for the various species of helminths present have remained similar to those previously reported.

Two herds in Victoria have been brought into the experiment, and assistance was provided to the Department of Agriculture in Western Australia for similar work in that State. One of the herds in Victoria comprised a number of identical twins but the egg counts have been too light in this herd to permit of any conclusions. In the second herd in Victoria larvae of *Haemonchus contortus, Trichostrongylus axei, Ostertagia ostertagi, Bunostomum phlebotomum, Cooperia oncophora, C.punctata,* and *Oesophagostomum radiatum* were recognized, but only those of *C.oncophora, T. axei,* and *O. osteragi* were abundant. In the first year's study, *C.oncophora* gave its maximum faecal egg counts in July to early November, *O. ostertagi* in August to November, and *T. axei* in October to early January. The counts of all three species then declined to a low level at which they have remained. All the calves also became infested with *Moniezia* sp. (*M. benedeni*), but the infestations were in general only short-lived.

(ii) *Host Reactions to Infestation with Haemonchus contortus.*—Studies are being made to determine the factors responsbile for outbreaks of haemonchosis. Observations on natural populations of this species have shown that when calves are first exposed to infestation the populations build up, either rapidly or gradually, to a maximum which is usually of comparatively short duration and is followed by a conspicuous and frequently rapid decrease to a low level at which the populations remain. In such animals the egg counts may reach a maximum of 4,000 eggs or more per g. of faeces but because this heavy infestation has such a brief duration, clinical signs of haemonchosis are not obvious. Under certain conditions, however, the resistance reaction fails to operate, high populations are maintained, and haemonchosis becomes evident. It has been suggested that these conditions are brought about by exposure to very large numbers of infective larvae or by inadequate nutrition, or possibly by both factors, and the matter is being investigated accordingly.

It has been found that worm-free animals when given a single dose of larvae maintain the period of maximum egg production for a few weeks at most, after which the count drops to a low figure. Animals given continuous large doses of larvae, up to 10,000 per day, react somewhat similarly. One group of animals, given 100 larvae per day, gave a more persistent population, but the egg count did not increase beyond a moderate figure. Other animals were given spaced doses but reacted similarly. The "self cure" phenomenon reported with *H. contortus* in sheep has also been seen in calves. All animals given more than one dose of larvae were eventually tested for resistance with test doses of 150,000 to 200,000 larvae and were then killed and examined. Evidence of a strong resistance was shown by practically all animals and was denoted by the presence of none or only a few adult worms and by the delayed development of the test infestations. After 56 days, worms of the test infestations were still in the fourth stage.

These animals were also tested weekly for antibodies, but only in one was the presence of antibodies detected. The animals discussed above were all fed lucerne chaff, which has given good growth rates. The work will be repeated with animals on a diet of lower nutritional value.

(*b*) *Faecal Examination as a Measure of Helminth Infestation.*—The results of studies on the relationship of liveweight, age, and faecal output to enable more accurate interpretations of faecal egg counts to be made have already been reported. Investigations have also been undertaken to determine whether corrective factors for faecal consistency would be of any value. On a dry matter basis, factors of 1.25 and 1.75 were obtained for soft and diarrhoeic faeces respectively. It was found, however, that the dry matter output for a 24-hr. period showed considerable variation. It was also observed that egg counts from hour to hour and from day to day for any given population of worms were also very variable, and that corrections for faecal consistency had little influence on these variations. It was concluded that variations from other causes were so much greater than that from faecal consistency as to make faecal consistency corrections of little value.

(*c*) *Amphistomes.*—Work on the pathology of amphistome infestation in cattle has been held in abeyance as the officer responsible for these studies is abroad. Studies on the taxonomy of this group of trematodes are being continued.

(*d*) *Worm Nodules* (Onchocerca gibsoni).—In Queensland, cattle are infested with two, if not three, species of Onchocerca, namely, *O. gibsoni* which occurs in nodules mainly in the brisket area, *O. gutturosa* which occurs in the connective tissue of the ligamentum nuchae and of the region of the subscapular cartilage and elsewhere in the body, and *O. fasciata* in the gastrosplenic ligament. Studies on the life history of *O. gibsoni* are complicated by the fact that the microfilariae of two, if not all three, species occur in the skin. Before these studies could be continued, therefore, it was necessary to determine whether the larvae of these species could be distinguished morphologically and if so, whether there might be any difference in their distribution in the skin of various parts of the body. To date the larvae of *O. gibsoni* and *O. gutturosa* have been studied but examinations based on the number, size, and distribution of the cephalic and caudal nuclei and on body measurements have not revealed any constant difference between them.

(*e*) *Bionomics of Infective Larvae of Gastro-intestinal Nematodes.*—(i) *Technique for Recovery of Infective Larvae from Soil and Pasture.*—Before commencing studies on the ecology of the pre-parasitic stages of the strongyle nematodes of cattle it was necessary to develop a satisfactory technique for recovering infective larvae from soil and pasture. An investigation of Baermann's technique and its modifications confirmed reports from other workers that they were unreliable and could not be used for quantitative studies. A method was, however, eventually developed which permitted a recovery of 70 per cent. or more of the larvae and was effective with both large and small numbers of larvae.

(ii) *Behaviour of Larvae on Experimental Plots.*—Dung pads containing eggs of several species of strongyle were exposed on grass plots. The soil and grass were examined at frequent intervals to determine the movements of the larvae and their longevity. It would appear that infective larvae may migrate downwards into the soil beneath the pad and they have been recovered at depths up to 2½ inches. They have also been found on grass 6 inch from the edges of the pad and sometimes up to 12 inches.

Data on the longevity of infective larvae indicate that few *Haemonchus contortus* larvae survive more than four and a half months, whereas many infective larvae of *Cooperia* spp. (*C. punctata and C. pectinata*) may still be present on the grass around the dung pad after five months. These are preliminary observations and the studies will be continued and intensified.

(iii) *Observations on Larvae on Natural Pasture.*—Pasture samples are being examined at weekly intervals from a calf pasture at Goodna. Observations were commenced in February and each sample has so far been dominated by the larvae of *Cooperia* spp., which have constituted up to 90 per cent. of the larvae recovered. *H. contortus* has recently shown evidence of an increase from 1 to 10 per cent. of the larvae recovered.

The total counts of larvae rose from 520 per lb. of pasture in February to 1,500 per lb. at the end of May. At the end of March, which was an extremely dry month, the count was only 250 per lb.

(*f*) *Anthelmintic Trials.*—Two field trials are in progress in which animals are being treated monthly with phenothiazine or with tetrachloroethylene. Weekly body weights are taken.

In the phenothiazine trial, groups are being given 0.2 g./lb. body weight from about one to two months old. The treatment has proved very effective in controlling *Haemonchus and Oeseophagostomum,* but as would be expected has had little influence on the populations of *Bunostomum* and *Cooperia.* Infestations with *Trichostrongylus* and *Ostertagia* have been too light to permit any conclusion. As yet there is no indication from body weight records that animals have benefited from treatment.

Tetrachloroethylene has been given at dose rates up to 10 c.c./80 lb. body weight in equal parts of liquid paraffin, and immediately preceded by 60 c.c. of 10 per cent. sodium bicarbonate to stimulate closure of the oesophageal groove and ensure direct passage of the drug to the abomasum. This drug has given excellent results against *Haemonchus* at dose rates as low as 7.5 c.c./80 lb. body weight, but even at 10 c.c./80 lb. was ineffective against *Bunostomum* and at most only partially effective against *Cooperia.* From results against *Haemonchus,* stimulation of the oesophageal groove reflex with sodium bicarbonate was successful in about 80 per cent. of the calves. In this trial also treatment has not affected body weight.

(*g*) *Blood Minerals of Parasitized Calves.*—Preliminary work has consisted of the determination of normal values for blood minerals in worm-free or lightly parasitized stall-fed calves. In 50 calves so far examined, serum calcium values were from 9.0 to 13.5 mg. per cent. (mean 11.3 mg. per cent.), serum phosphorus values from 5.5 to 9.3 mg. per cent. (mean 7.4 mg. per cent.), and values for mean corpuscular haemoglobin concentration from 29.0 to 35.0 per cent. The younger calves showed the higher values in all cases.

Blood analyses of two calves which carried heavy nematode infestations and were in a state of collapse disclosed severe anaemia and an extreme deficiency of calcium and copper.

4. Entomological Study of the Cattle Tick.
(Division of Entomology.)

Such problems as that of resistant ticks and the loss of toxicity of dipping fluids in vats may be solved by studies of the mode of action of toxicants on ticks, the improvement of dipping fluids of established efficacy, and the testing of new toxicants. However, reasonably good control of the cattle tick can be effected in all parts of the zone of distribution, using one or other of the available acaricides. Hence although the work listed above is continuing, more emphasis is now being placed on the methods of employing acaricides, making use of certain ecological factors. The most important investigations are concerned with the effects of pasture spelling and strategically timed dipping on cattle tick control.

(*a*) *Chemical and Biochemical Studies.*—(i) *Absorption and Metabolism of Chlorinated Hydrocarbons by Ticks.*—This investigation was started to provide a chemical method of assessing the resistance of strains of ticks to acaricides. The aspect most intensively examined in the last year has been penetration. It has been found that when DDT is dissolved in an homologous series of normal primary alcohols and applied to cattle ticks, the greatest penetration takes place with butyl, amyl, and hexyl alcohols. A considerable amount of DDT applied in amyl and hexyl alcohols cannot be accounted for in the analysis of DDT from inside and outside the ticks, and is considered to have been metabolized to products which are not detectable with the Schechter-Haller analytical procedure.

The penetration of gamma-BHC into BHC-susceptible and reputedly BHC-resistant ticks was compared, but no differences were found between the strains in the rates of penetration of the amounts of gamma-isomer retained within the ticks.

(ii) *Depletion of Acaricides from Cattle-dipping Vats.*—Studies have been made of the gamma-isomer content of BHC cattle dips. The actual gamma content is usually considerably below the value calculated from dehydrohalogenation analysis, or from the known rate of charging and replenishment. There is evidence that the greatest depletion of laboratory-stored dip samples occurs in the summer months. Chemical breakdown of gamma-BHC has also been demonstrated in some artificially produced hard waters.

Depletion of DDT in laboratory-stored preparations contaminated with dip detritus is indicated by an increase in the inorganic chloride content, and the presence of DDT breakdown products. However, the extent of DDT depletion so far recorded appears to be of little practical importance.

(iii) *Persistence of Acaricides on Cattle.*—Measurement of the amounts of DDT on samples of cattle hair collected at intervals after dipping or spraying, correlated with a study of reinfestation with larval ticks, suggests that the presence of more than 1,000 μg of DDT per g. of hair protects animals against reinfestation.

DDT and lindane were formulated with equal proportions of the chlorinated polyphenol "Arochlor 5460" as cattle sprays which, by analogy with the performance of this and allied synthetic resins in other fields of insecticide application, should have resulted in much greater persistency of the toxicants. However, no marked increase in the persistency of DDT or BHC on cattle resulted.

Coumarone-indene resins formulated with DDT produced a small increase in the persistency of the toxicant as measured by both chemical analysis of hair samples and the rate of reinfestation of the cattle with seed ticks.

(iv) *Malathion.*—This acaricide, which is an organic phosphate of relatively low toxicity to vertebrates, appeared to have some promise for tick control when tested in the laboratory, but in field trials its performance was rather erratic.

(v) *Dieldrin and Aldrin.*—Laboratory and field trials have shown that these preparations, particularly dieldrin, give a very efficient kill of ticks and prevent reinfestation for at least as long as DDT.

(vi) *Systemic Insecticides.*—Aldrin, dieldrin, and lindane, as solutions in peanut oil, were injected subcutaneously into animals at the rate of 25 mg./kg. body weight. The animals showed no symptoms of toxicosis. The younger stages of ticks on the dieldrin and lindane animals were killed. Hair samples taken from the lindane animal two days after injection were found to contain 117 μg. of lindane per g. of hair, while samples taken five days after the injection contained 21 μg. per g. of hair.

(*b*) *Biological and Ecological Studies and Field Experiments.*—(i) *Interaction of Life History Stages.*—To find whether there was any analogy with the phenomenon of larval nematode infestation in sheep affecting the population of adult worms, large numbers of larval ticks were placed on a bovine bearing a population of young adult ticks. No significant reduction in the infestation of adults occurred in comparison with a control animal.

(ii) *Effect of Fertilization of Ticks on Engorgement.*—It has long been suspected by workers on the cattle tick that engorgement of the female only follows fertilization. This was confirmed by removing all male nymphs and newly emerged males from small infestations isolated on a bovine by repellent barriers painted on the skin. Females in such areas deprived of males did not engorge completely, but retained the power to do so, when males were made available, for a week or so after ticks to which males had early access had engorged and fallen.

(iii) *Larval Survival.*—Work on survival of larvae throughout several seasons yielded a vast amount of valuable data on this important non-parasitic stage in the Brisbane area. Similar studies have now been carried out in the Rockhampton area, where larval survival in the hotter months has been found rarely to exceed three months from the time of fall of the adult tick.

(iv) *Seasonal Timing of Dipping.*—Populations of tick larvae in pastures in the Brisbane area undergo a very pronounced reduction in numbers in winter and early spring, owing to the adversity of conditions for reproduction of the species over late autumn and winter. However, a very small "turnover" of ticks occurs most of the time but progeny of ticks falling from late July to early September tend to hatch more or less simultaneously some time in September or October, according to the prevailing temperatures. A "spring rise" in the numbers of larvae attaching to cattle then occurs, producing an early or mid spring generation of engorged female ticks which may become the parents of heavy November, December, and January infestations. If these in turn are not more or less completely controlled very heavy autumn and late summer infestations result.

A strategic dipping programme was commenced, to detect the spring rise in the numbers of larvae attached to cattle, and to initiate a dipping programme which would prevent the fall of engorged female ticks for some months, and thus reduce the numbers of seed ticks in the pastures at a time when they are normally increasing. In practice it has been found that winter populations are sometimes considerable and the detection of the spring rise is somewhat difficult. Nevertheless the initiation in September of a schedule of dippings to prevent the scape of engorged females until the end of the year achieved such a worth-while degree of pasture disinfestation that dipping in January to April could be spaced at intervals of 7-10 weeks before pasture infestations commenced to build up again. By contrast, a herd in which dipping was neglected in spring and early summer because of low tick incidence on the cattle during that period was so grossly infested in January to April that control, even by monthly dippings in DDT, was extremely difficult.

The question of the cattle losing their tolerance to redwater fever as a result of such a programme scarcely arises. Under almost all conditions of management there appears to be a slight "leakage" of ticks which escape all but the most rigorous dipping programmes. These serve to continue the infestation of the pasture which is necessary to maintain the tolerance of th herds to piroplasmosis, but survivors can be kept dow to such numbers that worth-while disinfestation of th pastures is produced.

A strategic dipping programme may not material reduce the number of dippings, but a much mo efficient control of the ticks is brought about and infe tations likely to injure the cattle are avoided.

(*c*) *Pasture Spelling.*—An experiment was con menced at Rockhampton in April, 1953, to obtai further information on the effect of spelling a pastu on the number of treatments with DDT required to co trol ticks. In the control area ten to fourteen anima had the run of the entire 80 acres continuously, where in the spelling treatment a similarly stocked area wa divided into two by an electric fence. One portion this subdivided paddock was kept free of animals fro mid November, 1953, to early February, 1954. Th animals were then returned to this half, four days afte DDT spraying, and did not need treatment by mid Ma On the other hand, in the control paddock two spraying were necessary during the period. Prior to the transfer to the spelled half, the cattle required sprayin every five to eight weeks. After mid May the cattle i the spelled paddock were sprayed, although they sti carried only one-tenth of the number of ticks usuall accepted as a criterion for spraying. They were the returned to the half of the paddock they occupied i February. The observations on the longevity of th larvae are therefore confirmed.

(*d*) *Tick-free Areas.*—Certain areas within th broad zone of distribution of the tick are stated to b either free of ticks or so lightly infested that dippin is seldom necessary. Visits have been paid to certai of these areas in preliminary attempts to decide wha factors are responsible for the condition.

5. Production in Dairy Cattle Herds.

(Division of Animal Health and Production.)

(*a*) *Progress in the Zebu-cross Dairy Herd.*—Pr gress has been seriously retarded as a result of th relative infertility of the Sindhi x Jersey bull importe from the United States in 1952. In over 150 mating since June, 1952, he has succeeded in getting onl nine females in calf. Semen samples from this bu have been examined and the sperms found to be low i number, of very poor motility, and with an undue pr portion of abnormal sperms. Efforts are being made t improve the quality of the semen by treatment of th animal. In the meantime he is being persevered with a sire.

Data for lactation performance, coat colour, an body weight continue to be recorded, and an investiga tion into the nature of the phenomenon of coat sheddin in both European and half-bred cattle has commence

Macroscopic changes in the coat during shedding wer recorded at weekly intervals. At the same time sample of hair were clipped from the animals, the area of th clipped patch being measured. Trephined skin sample for histological study were then taken from the centr of the clipped area. Preliminary examination of th data from the observations on macroscopic change in the coat during shedding indicate that they follo a definite pattern, and that their progress may depen on the condition and physical well-being of the anima

(*b*) *Physiology of Milk Secretion.*—Studies in th field were discontinued at the end of 1953. An exper ment on the effect of unequal diurnal milking interva upon milk production was concluded. Data on udde capacity were analysed, and demonstrated a patter of physical and functional involution during lactatio Experiments on the duration of the let-down reactio in which the complications of "second let-down" were excluded, indicated that the degree of evanescence might be considerable within the period occupied by milking and that it varied greatly between cows.

One empty heifer was brought into lactation by implants of 3 g. progesterone and 100 mg. stilboestrol 120 days before, and 1.5 g. stilboestrol 30 days before, their removal and the commencement of milking. It produced 7,175 lb. of milk in 305 days, as against 8,275 lb. from its identical twin, which calved normally.

6. INVESTIGATION OF BEEF PRODUCTION IN AUSTRALIA.

(Division of Animal Health and Production.)

The following studies are under the direction of the William McIlrath Fellow in Animal Husbandry, who is located at the McMaster Laboratory.

(*a*) *Cattle Management investigations in the Southern States.*—These investigations are conducted by the Departments of Agriculture of New South Wales, Victoria, South Australia, Western Australia, and Tasmania, and the William McIlrath Fellow acts as co-ordinator for the observations at the twelve centres. Details of food intakes, liveweight changes, and carcase appraisal are recorded.

(*b*) *Stall Feeding and "Topping Off" of Beef Cattle.*—The practice of "topping off" by complete hand feeding is increasing and data were collected from four trials, one of which comprised 650 head of cattle. With one exception, the agreement between actual and calculated liveweight gains for the food consumed was very close.

(*c*) *Feeding Stud Cattle.*—Comprehensive nutritional and liveweight data continue to be collected from a Hereford stud.

(*d*) *Biochemical Investigations.*—Seasonal variations in the vitamin A, carotene, and inorganic phosphorus levels of the blood serum were studied in a herd of Shorthorn cattle in central Queensland. Compared with control cattle in southern New South Wales, low values for vitamin A and carotene were recorded on four of the six occasions when analyses were made. The oral administration of 1,200,000 i.u. vitamin A per head did not appreciably improve the serum values for vitamin A. This investigation emphasized the need for wider studies of blood vitamin A levels and the inclusion of liver biopsy samples. The analyses of the serum inorganic phosphorus revealed low values comparable to those recorded in cattle afflicted with "peg-leg" and suggested phosphorus deficiency.

7. GENETICS OF CATTLE.

(Animal Genetics Section and Division of Animal Health and Production.)

(*a*) *Animal Genetics Section.*—During the year a herd of dairy cattle were inseminated with frozen semen flown from the United States. The problems encountered in getting cows to the right stage in oestrus for success with this technique were largely solved. Work on beef cattle has been confined to study of the coat. The density of hair follicles is much the same for all European breeds with the exception of the Jersey, which is somewhat denser under comparable conditions. Both age and nutritional status have marked effects on density which have to be taken into account when making comparisons. Zebus are altogether denser, having rather more than 50 per cent. more follicles per square centimetre than Shorthorns. The first cross between Zebu and Shorthorn is intermediate between the parent breeds.

(*b*) *Division of Animal Health and Production.*—The beef cattle breeding investigations at "Belmont" were initiated with the mating of fourteen single-sire groups in late January 1954. Prior to this all cows had been identified, and where necessary calves had been identified and mothered.

(i) *Cross-breeding.*—Subgroups have been arranged with Hereford, Shorthorn, Zebu, and Africander bulls, each mated with 30 cows, half of which are Herefords and half Shorthorns. In all, twelve bulls and 360 cows are involved. To ensure comparable subgroups, bulls and cows were randomly selected before mating. The period of mating was limited to six weeks. Floods in February caused some upset to this mating as it was necessary to withdraw bulls from eight of the twelve families. No mismatings occurred and, after the floods had subsided and fences were repaired, it was possible to resume the programme.

Routine observations on the breeders have commenced with the monthly weighing of all animals.

(ii) *Northern-bred-Southern-bred Trial.*—The stock involved consist of two groups, each of one bull and 30 cows, representing animals typical of the Hereford breed in Queensland (northern) and in New South Wales (southern). The northern groups were bred near Rockhampton, Queensland, and the southern group at Armidale, New South Wales. Animals of the two groups and their progeny will be subjected to observations and measurements aimed at defining adaptation and production within a tropical environment.

In addition to the above there is a third, southern-bred group located at "Chiswick", Armidale, New South Wales. This group is identical with the southern-bred group at "Belmont" and its performance at Armidale will be contrasted with that of both groups at "Belmont".

All groups were mated in January, 1954, and monthly weighings of cows is proceeding at both centres.

(iii) *Zebu-cross Breeding.*—This group, consisting of 30 cows each containing 50 per cent. or more of Zebu blood, is being used for the investigation of methods which will later be applied in the larger herds of the main projects. The objective is to define, and to evolve methods of measuring, productive and adaptive characters. The cows were mated in March and April with Zebu bulls.

(iv) *Oestrus Studies.*—This study aims at the determination of the incidence of oestrus in beef cattle in a tropical environment. The investigation has been delayed by the floods. The herd comprises 80 Hereford cows which are being run with vasectomized bulls.

IX. ENTOMOLOGY.

1. GENERAL.

Throughout the agricultural, pastoral, and horticultural industries, Australia in common with most parts of the world suffers enormous losses from the depredations of insects. As seed, as growing crop, or as harvested food the products of the soil are continually subject to spoilation by insects of the many thousands of species. Before a campaign against any insect can be launched with reasonable hope of success, the life history and habits of the particular species must be thoroughly investigated and understood. The Organization's investigations involving the biology and control of insect pests, the biological control of weeds, and other aspects of entomology are mainly carried out by the Division of Entomology, with head-quarters in Canberra. Collaborative work is, however, undertaken by the Division on special problems in conjunction with other laboratories. Research on insects affecting animals is done in co-operation with the establishments of the Division of Animal Health and Production and is reported in Chapters VII. and VIII.; the Division plays a part in the investigations on the virus disease of rabbits being studies by the Wildlife

Survey Section (*see* Chapter X., Section 2). The Division co-operates with the Division of Forest Products in the study of pests of timber (*see* Section 13 of this Chapter, and Chapter XIV., Section 6 (*h*)).

Division of Entomology.—The emphasis of the Division's work continues to shift towards the more fundamental aspects of entomology. This results from an increasing realization that the development of effective control of insect pests lies more in a clear understanding of the basic principles of insect life than in the development of new insecticides and new methods of applying them. Naturally direct control measures must always have a place in the prevention of damage. However, it has been found that research on the factors which influence the abundance of insects, or the physiology or ecology of insects, leads to more intelligent application of direct control measures. This may result in improved control, or control at less expense when insecticides are used, or it may be found that by an adjustment of the environment chemical treatment is made unnecessary.

Current research on the cattle tick reflects the new approach. Although work is continuing on the improvement of dipping fluids, the emphasis has now shifted to: (*a*) experiments on the strategic timing of dipping, with the object of ensuring that from time to time all the ticks in a given area are exposed to dipping, and not merely those which happen to infest the animals at a given moment; and (*b*) the "spelling" of pastures, with a similar object. Another example is the current research on the air-tight storage of grain, which indicates that under air-tight conditions the gaseous environment becomes unsuitable for the development of insects which destroy grain, thus eliminating the need for application of any insecticides.

Work has been intensified on the study of insect populations, and the field studies commenced last year have developed to a stage where intensive observations on a few species can be undertaken. In Western Australia more attention is being given to ecological studies on the earth mite and lucerne flea than to chemical treatments, which have previously been regarded as being of more immediate importance.

Promising results have been obtained in the Argentine ant eradication campaign in Sydney, where the Division is co-operating with the New South Wales Department of Agriculture. All known infested areas have now been sprayed, which has reduced infestation to a very low level throughout the affected area, and has already eradicated the ant in some isolated areas. Experiments are continuing in Western Australia in co-operation with the Western Australian Department of Agriculture.

A new air-conditioned insecticide laboratory which has been under construction for some years was completed during the year and will make much more effective work possible on insecticides and insect toxicology. One new prefabricated glass-house has been erected and the two acquired last year are now in constant use. These facilities, however, do not satisfy the Division's need for more buildings which will supply the controlled conditions required in many of its investigations.

In May, 1954, at the request of the Agricultural Council, a conference was convened at Canberra by the Organization to discuss a proposal to carry out a trial campaign using a new strategy in locust control. It was attended by senior entomologists from all States.

The Division has commenced a study of the ecology and pathology of the black beetle. Although the pest is present in several States, this work will be done mainly in New South Wales in co-operation with the Department of Agriculture.

The Division is engaged in co-operative work with the New South Wales University of Technology on the formulation of cattle dips, and the surface chemistry of insect cuticular lipoids, and has provided material for work on the chemistry of ants. It is also co-operating with the Australian National University in experiments on the mechanism of insect transmission of animal viruses, and in other minor research projects; and with the Australian Forestry School in a small experiment on harvester ants.

The final draft of a list of common names of insects and related pests occurring in Australia has now been completed and is being prepared for publication.

2. INSECT PHYSIOLOGY AND TOXICOLOGY.

(Division of Entomology.)

(*a*) *Digestion of Wool by Insects.*—Further attention has been paid to the characteristic factor in which wool-digesting insects differ from other animals. namely, the possession of highly reducing midgut digestive juices. These reducing conditions disrupt the resistant disulphide bonds of keratin, and this reduced wool can then be degraded by proteolytic enzymes. Various systems which may be involved in maintaining the reducing conditions are being examined.

A study of cysteine desulphydrase in wool-digesting and other insects has been completed. This enzyme is responsible for the production of hydrogen sulphide from cysteine and is extremely active in the gut of the clothes moth larva, where it plays an important part in the degradation of keratin. Its presence accounts for the ability of these larvae to eliminate many metals as insoluble sulphides. Cysteine desulphydrase is present but in a far less active form, in some other insects including carpet beetle larvae, which are unable to excrete ingested metals as sulphides.

Another enzyme system which might have been implicated in the maintenance of reducing conditions is xanthine oxidase (which catalyses the oxidation of xanthine to uric acid) and the distribution and properties of this enzyme have been investigated in severa insects. Larvae of the clothes moth *Tineola* possess an extremely active xanthine oxidase, where as no activity was detected in larvae of the carpet beetle *Anthrenus flavipes* and only slight activity in cockroach adults and sheep blowfly larvae. Relatively little activity was found in the *Tineola* gut, whereas most resided in the remaining tissues. Methylene blue acted as a hydrogen acceptor under both aerobic and anaerobic conditions but molecular oxygen would not suffice. The clothes moth enzyme therefore bears some resemblance to bird xanthine oxidase.

(*b*) *Histochemistry of the Digestive Tract.*—The midgut of blowfly larvae provides excellent experimental material for the study of correlations between enzyme systems and cellular function. A series of histochemical tests demonstrates that there is a more striking functional differentiation in the midgut epithelium than is indicated by histological studies. This differentiation is most marked in the middle region of the midgut, the cells of which display a complex pattern of functions. The distributions of the following have been studied: lipoid, glycogen, iron, copper potassium, acid and alkaline phosphatase, dehydrogenases, cytochrome oxidase, and acetyl esterase.

(*c*) *Insect Muscle Biochemistry.*—A study of th Mg-activated ATP-ase of mammalian muscle has been completed. This work yielded important new knowledge on the specificity of this enzyme.

An extensive study of the molecular kinetics of th ATP-ase of myosins and actomyosins from variou sources has been initiated. This involves the preparation of myosin and actomyosin from insect and mammalian muscle; the determination of the effect on th nzymic activity of variations in pH, total ionic trength of the medium, and the nature and quantity of ivalent cations present; and finally, precise measure-nents of the kinetics of the enzyme action under speci-ed conditions.

Some basic differences between the proteins of insect nd mammalian muscle have been revealed and will be nvestigated more fully. In addition, new knowledge f the energetics of the process of interaction between TP and actomyosin, the primary reaction in muscular ontraction, has been gained. Such data form a neces-ary part of the background material on which any heory of the mechanism of muscular contraction must e based.

Some preliminary experiments have been undertaken n connexion with a projected study of the mechanical nd enzymic properties of glycerine-extracted fibres f the flight muscles of insects. This work will be xtended as more insect material becomes available.

(*d*) *Metabolic Sources of Chitin.*—The study of the netabolic sources of chitin in insect cuticle has been ontinued. Types of enzymic degradation of chitin nd chitin esters, such as might occur in a biological ystem, have been investigated. Chitin is very readily ulphated or nitrated but is very resistant to phosphory-ation. Chitin and chitin sulphuric acid are both roken down by the enzyme chitinase to *N*-acetyl-D-lucosamine, together with a trace of D-glucosamine. he pH for optimum activity is 4.8 for both substrates. hitinase is without action on chitin nitrate. Acid ydrolysis of chitin, chitin nitrate, or chitin sulphuric cid leads to the formation of D-glucosamine. It has een shown that chitin as isolated from biological naterial contains free amino groups.

(*e*) *Chitin-protein Association in Insect Cuticle.*—he problems connected with the association between hitin and protein in the insect cuticle are being ctively studied. The reaction of N-acetyl-D-gluco-amine (the recurring chemical unit of chitin) with -amino acids, peptides, and proteins has been investi-ated. It is considered that products of the Schiff ase type (azomethines) are formed but the combina-ion is unstable and is split even at biological pH values. ome of these Schiff bases have been synthesized.

(*f*) *Precursors of Cuticular Protein.*—The method or quantitative estimation of amino acids by filter aper partition chromatography has been widened to nclude all amino acids likely to be found in a protein ydrolysate.

Analysis of insect larval blood has shown the presence f the following free amino acids: cystine, aspartic cid, glutamic acid, serine, threonine, glycine, alanine, aline, tyrosine, phenylalanine, leucine, proline, gluta-nine, and asparagine. Arginine, methionine, and ossibly lysine are present in small quantities. The ossible presence of ornithine, β-alanine, dopa, and aurine requires confirmation. Tryptophane and istidine appear to be absent. Pre-pupal insect blood as a similar amino acid content but contains less sparagine and much more glutamine.

(*g*) *Influence of Nutrition on Reproduction.*—In-estigations on the relationship between larval and dult size and reproductive capacity of the Australian heep blowfly *Lucilia cuprina* have been completed. An dditional finding to those in previous Reports is that, lthough small flies lay fewer eggs, these eggs are of normal size and weight. If the larvae from these eggs are supplied with adequate food the resulting flies are of normal size. There is no indication of resorption of nlaid eggs.

As stated in previous reports, honeydew from coccids and the droppings of sheep fed on pastures low in protein (e.g., summer pastures) are each inadequate as protein sources for the maturation of eggs of *L. cuprina*. However, it has been found that the combination of these two foods provides the necessary proteins and amino acids for egg maturation. This is interesting in view of the fact that, in some localities, analysis of the crops of wild flies shows that they have been feeding on coccid honeydew.

Carbohydrate analyses have been carried out, by means of paper chromatography, of the honeydew from coccids living on five common eucalypt species near Canberra.

Work on the carbohydrases present in the salivary glands and gut of *L. cuprina* is almost completed. It has been found that the salivary glands and the gut secrete identical carbohydrases. These are amylase, α-glucosidase, α-galactosidase, and probably β-*h*-fructosidase.

3. Insects and Viruses.

(Division of Entomology.)

Some viruses are transmitted mechanically, the pathogen being carried directly on the mouthparts of the insect vector. Other viruses pass through the vector, being first ingested and then reinjected with the saliva. Mosquitoes have been shown to function as vectors of either type. Thus they transmit myxomatosis mechanically, whereas they transmit Murray Valley Encephalitis by the "biological" mechanism. It has now been shown that aphids also transmit by either mechanism. They transmit the mosaic diseases of plants mechanically, whereas they transmit the virus causing potato leaf roll, for example, only after ingesting it and injecting it with the saliva into a susceptible plant. Leaf-hoppers and thrips, so far as is known, transmit viruses only by the "biological" process.

(*a*) *Myxomatosis.*—In co-operative work with Professor Fenner of the Australian National University some strains of myxoma virus have been found to be more easily transmitted than others. Analysis of experiments has shown that on the average a mosquito (*Aedes aegypti*) acquires about 20 virus particles when it probes a myxomatous lesion on a rabbit injected with the standard laboratory strain. Each time it probes a susceptible rabbit roughly 11 per cent. of the virus particles on the proboscis are left in the skin. The viable virus is lost from the proboscis in other ways at the rate of about 16 per cent. of the infectious particles per day.

The "Lausanne" strain of myxoma virus from France has been used instead of the Australian standard laboratory strain in a similar experiment. Results suggest that there may be some advantages from the viewpoint of rabbit control in releasing the French strain of virus in Australia.

(*b*) *Potato Leaf Roll Disease.*—The virus causing this disease can be recovered from the haemolymph of the vector, *Myzus persicae*. The virus is transmitted by an aphid after a moult, and the aphid retains its infectivity for at least eight days; during this time it is able to infect many plants. Experiments suggest that the virus multiplies to a limited extent in *M. persicae*.

(*c*) *Rugose Leaf Curl.*—Work on the vector relationships of this disease awaits the establishment of virus-free colonies of the vector *Austrogallia torrida*. The occurrence of transovarial infection and the ability of some adults of *A. torrida* to pass the virus on to this progeny without themselves transmitting the virus to susceptible plants necessitates careful testing to ensure that colonies are in fact virus-free. Several colonies, established by selection and by heat treatment of adults (32-34° C. for eight days), have produced no disease symptoms for at least six months. During this time they have passed through two generations on susceptible indicator plants.

Heat inactivation of the virus in tomato plants has also been studied. A temperature of 36-37° C. for five days caused them to produce symptomless new growth for approximately six months, but the symptoms then reappeared.

(*d*) *Potato Purple Top Wilt.*—It has been considered that this important disease of potatoes is caused by the same virus that produces big bud in tomatoes. Work has been started to determine whether the two viruses have the same vector relationships.

4. POPULATION DYNAMICS.

(Division of Entomology.)

(*a*) *Theoretical and Laboratory Studies.*—Using the sheep blowfly *Lucilia cuprina* as the experimental animal, work has been continued upon the study of how populations accommodate themselves to external stresses. Populations have been subjected to many different kinds of adverse factors and it has always been found that populations react in a way which opposes the reduction in density which the adverse factors tend to produce as a primary effect. According to the circumstances, the operation of an adverse factor may increase or decrease density, or leave it unchanged. Commonly it reduces the density of some life stages and increases the density of the population at other stages. Because of this mechanism of compensatory reaction, populations are commonly able to maintain themselves in being in spite of very great stresses in the environment. A knowledge of the mechanism of such compensatory reactions is absolutely essential for the development of the most effective means of controlling pests.

In each of the cultures studied previously, the population was controlled by only one reactive factor, although different reactive factors were used in the different experiments. During the past year, a study was made of the effects produced when two or more reactive factors took part in the control of a single population. It was found that the populations automatically adjusted themselves to this comparatively complex situation. Both the average levels of the populations and the patterns of population change were influences by the interaction of these factors, but the basic characteristics of population control remained unchanged. A beginning has also been made with the study of populations living in fluctuating environments, by contrast with the populations studied in previous experiments which were cultured under constant conditions.

(*b*) *Field Population Studies.*—Last year the Division began long-term field studies on insect populations aimed at determining the factors responsible for regulating the numbers of different kinds of insect under natural conditions.

Seven species of Psyllidae and two of Coccidae were chosen for study. Preliminary investigations on these phytophagous insects occupied the first six months of the year. They included : (i) life cycle observations; (ii) observations on numerical distribution; (iii) studies on natural enemies; (iv) studies on the effect of populations of high density on the host plant.

The object of this work was to obtain sufficient preliminary information to allow of expansion to a programme of systematic broad-scale field studies designed to demonstrate the factors responsible for density governance.

It was possible to begin the second stage of the investigations during the latter half of the year and, for each species, much useful information has been collected for either one or two generations. The results agree with the leads given by the preliminary observations and lend support to the suggestion tha natural enemies are normally the density-governing agents of these insects.

5. LOCUSTS AND GRASSHOPPERS.

(Division of Entomology.)

The outbreak of the Australian plague locus (*Chortoicetes terminifera*) that developed in certain western outbreak areas in the late summer of 1953 continued in a much more severe form in the season 1953-54. In the Bogan-Macquarie outbreak area where continuous field investigations are in progress numerous swarms hatched and matured during the spring months. These migrated out of the area in an easterly to south-easterly direction, for the most par without ovipositing. From early December to March the Trangie area, at least, was free from swarms During the latter part of March and into Apri scattered flyers and loose swarms drifted into the district from the west and north-west and concentrated in the outbreak centres around Trangie, leading to the production of dense swarms, which laid heavily on the outbreak centres and then emigrated in a south-easterly direction, leaving a scattered non-swarming population behind.

These developments interfered to a considerable extent with the programme that had been laid down for determining the effect of the shrub-planting treatment of outbreak centres on the locust population Three outbreak centres had been planted with rows of the saltbush *Atriplex nummularia* some ten years previously, the plantings being arranged in the form of a hedge-like barrier between the oviposition and food-shelter habitats. A further outbreak centre had been fenced off from stock and ploughed, and the oviposition habitat had by this means been destroyed Each of the treated centres had been paired with an adjacent and similar "control" centre, and the effect of the treatments was to be estimated by periodical comparison of the locust densities on the treated and control centres. The treatments were designed primarily to reduce the rate of multiplication of locusts in the treated outbreak centres—hence an invasion by swarms, which settle to some extent at random, could be expected to obscure the treatment effects.

During March when swarms had been absent for some three months, locust counts were commenced along fixed yard-wide lanes spaced at equal intervals across each outbreak centre. During the period of counting, the infiltration of immigrants from the west (see above) began and to some extent vitiated the results. Nevertheless some indication of lower densities on the treated outbreak centres was obtained and useful experience with the technique gained. When subsequently the invasion of flyers greatly intensified, it was noted unexpectedly that the densities obtained, and the tendency to form swarms, remained less on the treated than on the untreated outbreak centres, notwithstanding that the density differences were not due to differential multiplication by breeding, or to differential survival, but solely to differential settling by the invaders. These results are far from conclusive, but if they can be confirmed by further observations the shrub-planting treatment will be shown to have had a definite effect in limiting swarm formation in the outbreak centres.

6. PASTURE COCKCHAFERS.

(Division of Entomology.)

Only a limited amount of work has been done on this group of pests during the past two years, but preparations have now been made to begin an ecological study of the black beetle (*Heteronychus sanctae-helenae*), which is a serious pest of crops in the New

South Wales coastal areas and in other parts of Australia. The work will be carried out in co-operation with the New South Wales Department of Agriculture, which has carried out and will continue extensive control investigations on this pest. Extremely heavy infestations were present in the autumn of 1954 and a joint survey was made of the affected areas, mainly with a view to selecting suitable sites for ecological studies.

Dr. R. L. Beard, who visited Australia on a Fulbright Fellowship, carried out investigations into the bacterial and fungal diseases of cockchafer larvae. A milky disease infecting the larvae of the black beetle was discovered late in 1953 when he visited the south coast of New South Wales with an officer of the Division.

7. PASTURE CATERPILLARS.

(Division of Entomology.)

Although the officer in charge of these investigations has been overseas for most of the year, regular light trapping has been carried out in Canberra to ensure the continuation of long-term records of certain species under observation.

Aestivating adults of the bogong moth *Agrotis infusa* have been kept under observation on the Brindabella Range, Australian Capital Territory.

8. RED-LEGGED EARTH MITE AND LUCERNE FLEA.

(Division of Entomology.)

(*a*) *Population Studies.*—The insecticide experiments described in previous years are now being reduced to permit of intensified work on the ecology of these pests. Population studies of the lucerne flea, red-legged earth mite, and bdellid mite were commenced during 1953 and although no definite conclusions can be drawn from the one year's observations some interesting points have arisen. An area relatively free of bdellid mites was chosen at Walebing, Western Australia, and the distribution of lucerne fleas over the paddock was mapped at three-weekly intervals. Clearly defined areas of high density could be mapped at the beginning of the season. As the season progressed the flea population in the areas of high density declined and that in the areas of low density increased so that at the end of the season the picture was completely reversed. No clear-cut reasons for this change are yet available, but there appear to be no environmental factors responsible. Competition for space or some food factor or the relative unpalatability of previously infested food plants appear likely to have influenced the population. A similar but less distinct change was also observed in another area at Waroona, Western Australia, but here the picture was complicated by the presence of a very high population of predatory bdellid mites and also a dense population of earth mites. The presence of the former resulted in a rapid decline in the overall lucerne flea population, so that at the end of the season it was at a very low level. Supporting evidence for the above hypotheses on the factors limiting the population density was obtained from insecticide experiments where the killing of a high proportion of the lucerne flea population in a pasture resulted in a significant increase in the earth mite population.

A start has been made on a study of the distribution of the bdellid mites in the south-west of Western Australia and samples have been collected from over 200 sites from the Murchison River in the north to Augusta and Hopetoun in the south. Observations indicate that not all bdellid mites are predatory on the lucerne flea.

(*b*) *Physiological Studies.*—Further studies of the aestivating eggs of the earth mite have shown clearly that after completing their development in the mite these eggs enter a diapause lasting for about two months in the field, where they are exposed to very high temperatures and very low humidities at the soil surface.

A study of the effect of temperature on incubation period has confirmed a previous experiment showing that hatching would not occur above approximately 20° C., despite the presence of adequate moisture.

(*c*) *Effect of Earth Mite on Pasture Production.*—The first two years' observations were described in the previous Annual Report. In the third season the elimination of the mite resulted in an increase of 21 per cent. in total yield of early season (June) growth and 3 per cent. in total yield of late season (October) growth. Subject to more detailed analysis the results indicate an interesting change in the composition of the pasture, subterranean clover and grasses being increased in both early and late season, while capeweed was reduced throughout the season and *Erodium* in the late season.

(*d*) *Insecticide Experiments.*—In small-scale experiments at the Institute of Agriculture, Nedlands, Western Australia, eleven new insecticides and acaricides were tested against the now standard DDT. None was as effective as DDT, but DCPM and Dilan showed some promise and will be retested in the next season.

A large-scale experiment using the boom spray was carried out at Coomberdale, Western Australia, the treatments being parathion at ½ oz./acre, parathion at ½ oz. + DDT at 4 oz./acre, and dieldrin at 4 oz./acre. Parathion + DDT gave excellent control of both lucerne flea and earth mite, though the population of the former returned to normal after three months. Neither parathion (alone) nor dieldrin affected the earth mite, but again parathion gave a complete initial kill of the lucerne flea, the population returning to normal after three months. Dieldrin achieved some control of the lucerne flea with some apparent residual effect, and further tests with it are planned.

9. SHEEP BLOWFLY.

(Division of Entomology.)

(*a*) *Ecological Studies.* — From trapping data obtained in December, 1952, tentative population density measurements have been made of *Calliphora augur* and *Calliphora stygia,* the common domestic nuisance blowflies in southern Australia. Calculations based on the ratio of wild flies caught to retrapped marked specimens, of which known numbers had been liberated, indicated that even when an improbably high daily mortality of 25 per cent. of marked specimens was allowed for, the population density of *Calliphora augur* was 195-275 flies/acre and of *C. stygia* 50-80 flies/acre. These figures contrast strongly with the population densities of the sheep blowfly, *Lucilia cuprina,* which average about two flies/acre, and indicate why the *Calliphora* species are such a prominent feature of the Australian scene in the warm weather. Although the *Calliphora* species are unimportant in comparison with *Lucilia cuprina* as sheep blowflies they are extremely important as competitors of this species in carrion.

10. CATTLE TICK.

(Division of Entomology.)

The Division's work on the cattle tick is described fully in Chapter VIII., Section 4.

11. INSECT PESTS OF STORED PRODUCTS.

(Division of Entomology.)

Problems of grain storage have received most attention during the year. The study of the effects of airtight storage conditions on the grain weevil *Calandra granaria L.* has been completed and it has been shown that all stages are killed by the reduction in oxygen due to the respiration of the insects and the grain. The adults have been shown to be the most resistant stage. Measurement of the respiratory quotient of this species showed that the accumulation of carbon dioxide which occurs as oxygen is depleted is insufficient to play any part in the death of the insects.

The time taken for the insects to be killed in an air-tight silo has been calculated and indicates that under suitable conditions the method may be of use for storage periods as short as three months. The amount of damage that the insects can do between the time of sealing up and their death was estimated and it has been shown to be negligible in a well-sealed silo.

In order to carry out experiments on a larger scale than is possible in the laboratory a steel silo of 1,000-bushel capacity has been purchased and erection has started.

The information so far gained about the method confirms the desirability of carrying out full-scale field trials. If this can be done and proves successful an economic method of grain storage will be available that will enable grain to be held as long as desired without loss or deterioration.

Quite severe infestation by the large strain of *Calandra oryzae* L. was found in maize cobs before harvest in north Queensland.

12. Biological Control.

(Division of Entomology.)

Much of the biological control work mentioned in the previous Report has continued and in addition work has begun on several other problems. These include the biological control of ragwort (*Senecio jacobaea*), the introduction of parasities of the brown vegetable weevil (*Listroderes obliquus*) and of wax scales (*Ceroplastes* spp.), and a study of the parasites and predators of aphids in Australia. These four investigations will receive considerable attention in the next few years.

(*a*) *St. John's Wort* (Hypericum perforatum).—An additional 20,000 chrysomelid beetles, mainly *Chrysomela quadrigemina* (= *C. gemellata*), were distributed in New South Wales during 1953 in the Jingellic district and at Kootingal near Tamworth. Beetle colonies are making good progress in the Orange and Sodwalls districts, while colonies at Tuena continue to develop satisfactorily.

A colony of the cecidomyid gall-fly *Zeuxidiplosis giardi,* which mainly produces galls on the terminal shoots of *Hypericum* spp. resulting in restriction of the plant's growth, was introduced from California in March, 1953. Liberations were made in two separate areas in New South Wales during October. The liberation area at Tuena was inspected in June, 1954, when galls of varying ages were found on some *Hypericum* plants.

(*b*) *Insect Problems.*—(i) *Cabbage Moth* (Plutella maculipennis).—Of the introduced parasites of this species only *Apanteles plutellae* continues to be cultured and distributed to the States. Of the established parasites, *Angitia cerophaga* is the most abundant. *Diadromus collaris* seems to have increased since the introduction of the Italian strain of this species. *Apanteles plutellae* is apparently already established, though it is recovered in small numbers only. The host has evidently declined markedly in abundance since the biological control work was begun; and on experimental plots this year in Canberra, cabbages suitable for marketing were grown without the use of any insecticide.

(ii) *Cabbage White Butterfly* (Pieris rapae).—Parasitism remains at a very high level. *Apanteles rubecula* is now regarded as permanently established, though still far less numerous than *Apanteles glomeratus. Apanteles rubecula* cannot effectively parasitize *Pieris* because it has been found that the eggs are encysted by the haemocytes of the host larva.

(iii) *Green Vegetable Bug* (Nezara viridula).—Further introductions of *Trichopoda,* a tachinid parasite, were made from Florida and the British West Indies. It is now considered that *T. pilipes* F. is merely a colour variety of *T. pennipes* F.; both varieties were introduced this year. Recoveries of *T. pennipes* have again been made this season, but its establishment is uncertain. The factors affecting diurnal emergence periodicity in this species are being studied. The two egg-parasites, *Microphanurus basalis* (West Indian strain) and *Ooencyrtus submetallicus,* continue to be cultured and liberated on a large scale. Special features of reproduction in *O. submetallicus* are being investigated.

(iv) *Queensland Fruit Fly* (Strumeta tryoni).—Field work has begun to assess the suitability of areas for forthcoming liberations of the parasites imported from Hawaii. *Opius thaiensis* (?), *O. longicaudatus,* and *O. oophilus* have been cultured on *Strumeta tryoni.* Efficient mass culture methods have been developed for the first two.

Field collections confirmed that the incidence of parasites attacking *S. tryoni* in cultivated fruits is very low, but blackberry may prove an important host affecting the fruit fly-parasite relationship.

Field studies in Coff's Harbour and Grafton (New South Wales) indicate that the fruit of native trees are of little importance as reservoirs of Queensland fruit fly. Coff's Harbour has been chosen as suitable for the release of imported parasites because of the mild climate, high *S. tryoni* population, availability of host fruit almost all the year round, low incidence of existing parasites, and presence of many wild tobacco plants. The fruit of these are infested by *S. cacuminata,* which in the laboratory can be parasitized by *O. longicaudatus* and *O. thaiensis* (?).

(v) *Potato Tuber Moth* (Gnorimoschema operculella).—A field survey has shown that *Copidosoma koehleri* is established over a wide area of the potato-growing districts of Queensland and New South Wales, including many districts quite removed from any liberation site. In most areas except in Queensland the percentage of parasitism is too low to be of economic importance, but there is evidence of a gradual increase in some districts.

(vi) *Red Scale* (Aonidiella aurantii).—The establishment of the introduced *Comperiella bifasciata* in the Murray valley has been confirmed.

(vii) *Wax Scales* (Ceroplastes destructor, C. rubens).—With the co-operation of Kenya entomologists, a comparison has been made of *C. destructor* from New South Wales and the *C. destructor* on coffee plants in Kenya. It has been found that the Kenya species is wrongly named, but that a wax scale identical with the New South Wales *C. destructor* is present, though very uncommon, on other hosts in Kenya. This discovery provides a new basis for work on the biological control of this species. Parasite introductions against *C. destructor* and *C. rubens* will be made in the course of the next few years.

13. Termites and other Wood-destroying Insects.

(Division of Entomology.)

(*a*) *Termite Investigations.*—The assessment of the termite resistance of timbers, timber treatments, &c., by the standard laboratory colony technique has been continued during the past year. Once again it has been possible to carry out tests with the important economic species *Coptotermes acinaciformis* in north Queensland. A total of 743 test colonies was installed, comprising 387 of *C. acinaciformis*, 174 of *C. lacteus*, and 182 of *Nasutitermes exitiosus*.

Materials submitted to tests during the past year include commercial timbers from Australia, Africa, New Guinea, and Malaya, rubber- and metal-sheathed cables, treated plywoods and hardboards, and antitermitic chemicals.

The more important test results were: (i) that plywood made from karri (*Eucalyptus diversicolor*) can be termite-proofed effectively by momentary dipping of the veneers in suitable preservative solutions, such as sodium pentaborate or a mixture of zinc chloride and arsenic pentoxide, before bonding; (ii) that aldrin possesses very promising preservative properties, being superior to either chlordane or dieldrin in this respect.

A limited number of field tests of timbers and preservative treatments are in progress around mound colonies of *C. lacteus* and *N. exitiosus*, and a detailed report of the condition of samples in the International Termite Exposure Test after 24 years' service was prepared and forwarded to Madison, United States of America.

Soil poisoning tests around mound colonies of *N. exitiosus* and *C. lacteus*, and subterranean colonies of *C. frenchi* and *Heterotermes ferox*, have shown that 5 per cent. pentachlorophenol, 5 per cent. sodium pentachlorophenate, creosote, 10 per cent. sodium arsenite, 5 per cent. DDT, 2 per cent. chlordane, and 0.1 per cent. dieldrin all afford some protection. However, in the tests against *N. exitiosus*, some of which have been installed for five years, pentachlorophenol has failed badly in the fifth year while creosote, sodium pentachlorophenate, and sodium arsenite show varying degrees of breakdown.

(*b*) *Lyctus Investigations*.—The dietary studies of *Lyctus brunneus* larvae have continued and it has been shown that normal development is possible when starch in the synthetic diet is replaced by glycogen. Although the total methanol extracts of either *Melicope australasica* or *Cryptocarya glaucescens* (two resistant species) were toxic when added to the synthetic diet, none of the various fractions of these extracts showed any toxicity and this investigation has been abandoned. Work is now proceeding on the effects of various sterols and halogenated sterol derivatives on the growth of the larvae.

A preliminary survey of the *Lyctus* susceptibility of 45 species of Queensland timbers has been commenced.

14. ARGENTINE ANTS.

(Division of Entomology.)

The Division's work on the Argentine ant was carried out in the three States affected by the pest. In Sydney the full-scale eradication campaign, which is being carried out in co-operation with the New South Wales Department of Agriculture and local government bodies, was continued with promising results.

New infested areas discovered in Sydney since the work began have brought the total to 64 separate areas totalling nearly 3 square miles. The new areas were mostly less than 10 acres in extent and the complete spraying of all known infestations presented no difficulty. After the 1,161 acres treated in 1952-53 had been surveyed for surviving colonies it was decided to apply a second complete spray to areas with a high incidence of small colonies and to "spot" spray isolated infestations. A total of 281 acres had been re-treated by May, 1954. A 2 per cent. chlordane spray was used at first, but in the later part of the season an 0.75 per cent. dieldrin spray was used. An average of 61.8 gal./acre was applied.

In Western Australia, with the co-operation of the Western Australian Department of Agriculture, it was found that a 2 per cent. dieldrin spray applied two and a half years before was still killing ants invading the treated area. A 1 per cent. spray was still killing ants one year after application and an 0.5 per cent. spray had eradicated them from treated blocks except where soil had been disturbed. Aldrin and DDT gave results inferior to dieldrin.

During the year the University of Melbourne requested assistance in controlling the Argentine ant, and the University grounds were used as an experimental site to test under Melbourne conditions the sprays and methods used in Sydney.

15. INSECTICIDE INVESTIGATIONS.

(Division of Entomology.)

During the year the insecticide section moved to new premises specially designed for laboratory work in insect toxicology. Part of this building, comprising laboratory, culture, and testing rooms, is air-conditioned, and forms a compact unit which has greatly facilitated the work in progress.

In the study of factors influencing the susceptibility of insects and the toxicity of insecticides, adult houseflies of an insecticide-susceptible laboratory strain have again been the principal test insects employed. The susceptibility to DDT of flies of uniform age was found to vary with pre-adult development time. Flies maturing early or late were more susceptible than those with an intermediate rate of development. As this factor was not taken into account in previous work on the variation in susceptibility with age of test flies, some of these experiments are being repeated, using DDT and BHC.

The distribution of susceptibility in experimental batches of flies, and the variations in susceptibility of successive generations, are being studied in the insecticide-susceptible strain and in a strain which is being selected for resistance to DDT. The two strains are also being compared in certain aspects of their biology which have a bearing on rearing procedures, namely, life cycle, fecundity, and mortality during each developmental stage.

16. TAXONOMY.

(Division of Entomology.)

Two papers published during the year on the genera *Heliothis* and *Persectania*, which contain important species affecting various crops, are good examples of the relationship that must exist between ecology and taxonomy. They reveal that certain common pest species have been incorrectly identified.

A monograph on the taxonomy, phases, and distribution of the genera *Chortoicetes* and *Austroicetes*, which include most injurious Australian locusts and grasshoppers, has been published. Other taxonomic work on the Australian Acrididae is continuing in cooperation with the Academy of Natural Sciences of Philadelphia. The second volume of James A. G. Rehn's monograph was published in July, 1953, and work on the third volume is progressing steadily.

Full revisions of the families Nemestrinidae and Apioceridae (Diptera) have been published during the year. Other dipterous groups receiving attention are the Tachinidae, Calliphoridae, and Cyrtidae.

A complete revision of the Dynastinae (Scarabaeidae) will shortly be ready for publication. Most of this work was done by an officer of the Division at the Imperial College in London during the tenure of a studentship.

Work is continuing on the Formicidae (ants) by an Australian specialist with the support of the Commonwealth Scientific and Industrial Research Organization.

Other groups being studied within the Division are the Chalcidoidea and other parasitic Hymenoptera (notably the Cynipoidea and Cleptidae), Isoptera (termites), Blattidae (cockroaches), and Psyllidae.

A large number of insect specimens have been identified for research institutions and government departments in Australia and New Guinea. Specimens for identification have also been received from several institutions and individuals overseas.

X. WILDLIFE.

1. General.

In every country in the world mammals and birds, both native and introduced, affect primary production and other human activities in a variety of ways. In Australia, what may conveniently be termed wildlife problems range from that of the rabbit, the country's most serious pest, to the mutton bird, on which a small but valuable local industry depends. Kangaroos, possums, and ducks of various species may be pests at various times and in parts of their range, while calling for conservation elsewhere because of their economic value or their importance as game. To deal with wildlife problems that called urgently for solution or merited scientific study for other reasons, the Organization established its Wildlife Survey Section in 1949.

Wildlife Survey Section.—During the first two or three years of the Section's existence its time was virtually monopolized by investigations of the rabbit and its control, and particularly by the virus disease myxomatosis which, after its successful liberation in 1950, has brought annually increasing benefit to the country. The peak mortality in rabbits over the greater part of south-eastern Australia was achieved during the summer and autumn of 1952-53; and the resulting benefit to pastoral production has been estimated at approximately £50,000,000.

As a result of increases in the staff, it has recently been possible for the Section to enlarge the scope of its rabbit investigations, to intensify work on some projects which had hitherto only been given preliminary attention, such as the study of the ibis and of kangaroos and euros in north-western Australia, and to initiate one or two new minor investigations.

In many of its investigations the Wildlife Survey Section depends materially on collaboration with State Departments, with Universities (particularly the Australian National University), and with other branches of the Organization; while most of its field work would be impossible without the assistance of individual landholders. The Western Australian Department of Agriculture has provided the accommodation and has made possible the establishment of a field station in the North-west Division for the investigation of the kangaroo and the euro problem; and close collaboration is maintained with its Vermin Branch in the rabbit investigations being carried on in the State. In connexion with work on myxomatosis and other aspects of rabbit control, close co-operation is maintained with the Vermin and Noxious Weeds Branch of the Victorian Department of Lands and Survey, and with the Tasmanian Department of Agriculture. The expansion of the duck investigations has made it possible for the Section and the Victorian Fisheries and Game Department to help one another to a useful degree.

The Section has established very close relations with the Antarctic Division of the Department of External Affairs, and has taken on a consultant and advisory role in connexion with the biological research carried out by the Australian National Antarctic Research Expeditions.

During the year, the head-quarters of the Section left the cramped and makeshift premises that it had been occupying at Black Mountain, and established itself at "Gungahlin", an old homestead on the outskirts of Canberra, which provided accommodation of exactly the type required.

2. Rabbit Investigations.

(Wildlife Survey Section.)

(*a*) *Myxomatosis.*—The investigations fall into three main categories: (i) regional surveys carried out to assess the seasonal performance of the disease and to collect information that might explain the local variations; (ii) intensive investigations into the ecology and behaviour of insect vectors; (iii) work on variant strains of the virus.

Just as the full effects of the disease in the 1952-53 season had not been assessed when the last Report was written, more information has to be collected before the 1953-54 picture is complete. By the winter of 1953, myxomatosis had spread until it was virtually coextensive with the distribution of the rabbit in south-eastern Australia, and kills ranging (in the main) from 75 to 90 per cent. or better occurred over an enormous area extending from southern Queensland to South Australia (a substantial portion of which State benefited) and including almost all of New South Wales and Victoria. The performance of the disease remained disappointing in Tasmania and Western Australia.

The unexpectedly good results obtained in 1952-53 were a reflection of a seasonal rainfall that favoured the widespread breeding of insect vectors, particularly the mosquito *Anopheles annulipes*. The much drier 1953-54 season resulted in a marked geographical restriction of disease activity as compared with the previous year, good kills in the main being confined to the neighbourhood of waters. Luckily dry conditions militated against a rapid and extensive build-up of rabbit numbers, and the overall rabbit situation remains highly satisfactory over most of south-eastern Australia. The response to the rains of late January and early February, in the form of increased diseases activity when and where it might have been expected, provided additional evidence of the dependence of epizootics on water-breeding insects. During the past season, *Culex annulirostris* (the first mosquito to be implicated as a field vector in Australia) was found to have played a more important role than *A. annulipes* along the Murray River and elsewhere.

General observations had indicated that, over much of south-eastern Australia at any rate, useful kills by myxomatosis depended primarily on the abundance and activity of one or two species of mosquito, and that the habit of *Anopheles annulipes* of resting in rabbit burrows and apparently even feeding on the animals underground was an important factor in transmission. The vector studies now under way in the Riverina are designed to place these indications beyond doubt. On three experimental sites typical of the major habitats of this region—river frontage, foothill valleys, and plain country with sandhills—the production, activity, and feeding behaviour of mosquitoes are being studied in relation to seasonal changes in the nature and extent of breeding waters and the local incidence of the disease. The dry season has prevented the collection of all the data that were hoped for; but valuable information has been obtained and the study should point the way to a method of prediction, at least a month or two ahead, of the vector situation during that season of the year when the transmission and spread of myxomatosis normally occurs. The dry season, resulting in generally low numbers of *Anopheles annulipes,* has also interfered with the progress of the study of mosquito behaviour in rabbit warrens (for which a system of artificial burrows has been constructed.) Preliminary experiments, however, have confirmed the suspicion that *Anopheles* will bite rabbits underground.

In co-operation with entomologists from the School f Public Health and Tropical Medicine in Sydney, n ecological vector study is being carried out at Colo Vale, near Mittagong, New South Wales. This area iffers from the regions further west, where *A. annulipes* nd *C. annulirostris* are of dominant importance and nyxomatosis outbreaks are usually short and sharp. The observations at Colo have failed to implicate any pecies as the main vector, but suggest that a number f insects may contribute to the transmission of the lisease to produce a low level of infection which, in ime, has effected a useful reduction in rabbit numbers. Conditions at Colo Vale are now believed to be typical f substantial areas of coastal and near coastal country n eastern Australia where potential myxomatosis ectors occur in greater variety than further inland, vhere *Anopheles annulipes* is of much less importance nd appears to have a somewhat different behaviour attern, and where the time-table and intensity of lisease outbreaks cannot be so easily explained or redicted.

Research on the virology of myxomatosis is centred n the Microbiology Department of the Australian National University at Canberra, and the Wildlife Section co-operates by collection in the field of material nd data required for the laboratory studies. The Section has, however, continued work on a strain of he virus collected from a local outbreak area. This “Uriarra” strain is typical of the many variants of educed virulence that have appeared spontaneously in he field, and has now been established as the most ttenuated of these natural mutants. When transnitted by contact the Uriarra strain has shown a case nortality rate of only 21 per cent., though when ransmitted by mosquitoes its lethality is somewhat nhanced. (A satisfactory explanation of this interestng observation has not yet been discovered; it is ossible that a mixture of strains will be involved.) The Uriarra strain has proved of great value in aboratory investigations for which a virus with a very igh case mortality rate would be unsuitable; e.g., it as been used by Professor Fenner of the Australian National University in his studies of the “passive mmunity” of young rabbits.

(*b*) *Rabbit Census Investigations.*—The ability to ssess population densities, and changes in populations lue to the operation of control measures, with reasonable ccuracy is of key importance in many of the Section's abbit investigations, and the most promising of the vailable techniques are being studied and checked. Satisfactory tagging and dyeing methods have been ound for the marking of rabbits. Using a technique of live-trapping, marking and release, and the standard “Lincoln Index” calculations, a census of the populaion of individual warrens was obtained with adequate accuracy; but the method cannot be regarded as suitable for dealing with the total population of an area. In many of the Section's investigations (e.g., when estimates of mortality caused by myxomatosis are required) reliance has to be placed on “traverse sight counts”. Experiments are in progress to check the accuracy of these counts, and to determine the factors causing variability which, unless understood, make it impossible to improve the technique.

During the course of the census experiments interesting observations were made on predation by little eagles and goshawks. These confirmed earlier results which showed that birds of prey concentrated on the kittens, and that even in areas where hawks were exceptionally abundant the resulting mortality was inadequate to prevent the rabbits' rapid increase.

(*c*) *Studies on Poisoning.*—Work on poisons and poisoning is continuing in Tasmania, where the Department of Agriculture is carrying out a large-scale campaign using sodiumfluoroacetate (“1080”). The Wildlife Section has co-operated with the State Department in three experiments designed to obtain an accurate assessment of the efficacy of this poison. The trials were carried out in completely netted paddocks, and the resultant kill was determined by the collection and counting of carcases and the digging out of every burrow. The evidence obtained confirmed the indication, based on widespread practical experience, that “1080” was highly efficient; but it also demonstrated the need of modifying the technique when poisoning operations were undertaken during the breeding season. It was found that there was an unsatisfactory kill among very young kittens, owing to the fact that they did not wander far from their warrens.

Before progress could be hoped for in the improvement of general poisoning techniques, it was found necessary to gain a better understanding of the feeding behaviour of rabbits under natural conditions. For this purpose a number of netted enclosures, each several acres in area, have been built on a grazing property in the Midlands. For the series of experiments now in progress, these enclosures are stocked with rabbits at a natural density which are allowed to acclimatize themselves before the study of their behaviour in relation to “free feed” and poison baits is started. A surprising number of factors leading to disturbance and variation of individual behaviour have been disclosed and some valuable information has been obtained, e.g., on the part played by the plough furrow, and the nightly “build-up” in the amount of free feed taken. The Tasmanian experience provides a good example of the danger of attempting short cuts in the search for information of practical value.

3. Kangaroo Investigations.

(Wildlife Survey Section.)

Following preliminary observations and experiments mentioned in the last Report, a field station for the intensive investigation of the local kangaroo and euro problem has been established at “Woodstock”, between Port Hedland and Marble Bar in north-western Australia, with the co-operation of the Western Australian Department of Agriculture. The programme of research, covering practical poisoning trials and ecological and behaviour studies, has been laid down.

4. Mutton Bird Investigations.

(Wildlife Survey Section.)

The joint investigations with the Tasmanian Fauna Board of the economic biology of the mutton bird (*Puffinus tenuirostris*) were continued during the year on the Bass Strait islands. The intensive study, started the previous year, of the life cycle of the breeding birds was concluded during the current season by continuous observations covering the period from egg laying in January to the departure of adult and young birds from the islands in May.

The highlight of the continuing observations on Fisher Island was the recovery of six birds which had been hatched there in January, 1950. As only nineteen young birds were reared on Fisher Island in the 1949-50 season, this represents a return of nearly 32 per cent. In addition four birds of the 1950-51 hatching were checked in. None of these young were identified as breeding birds, though several had brood patches. It is hoped that definite evidence as to the degree to which young birds return to breed on their natal islands will be obtained at next November's field work on Fisher Island.

During the season under review a study of the parasites of mutton birds was undertaken, and an effort made to determine the cause of the disease of the young birds known as “limey bird” sickness.

5. Ducks and Rice Cultivation.

(Wildlife Survey Section.)

Last year's largely preliminary investigations have been consolidated into an intensive programme covering the assessment and analysis of economic damage, the feeding habits of the more important duck species occurring in the Riverina, their breeding biology and their local population fluctuations and movements. The last rice season has been marked by an almost total absence of duck depredations. Comparison of conditions over the past three years has made it clear that by far the most important factors determining the degree of depredation by ducks of irrigated rice crops in any season are those affecting on a large scale the breeding and movements of the three most important species—the black duck, teal, and maned goose (wood duck). A study of the breeding biology of these ducks in the Murrumbidgee Irrigation Areas has accordingly been initiated, and with it a programme of banding (ringing) which should in time provide data on the nature and extent of the birds' movements and other points of interest. The Section's biological and banding activities should tie in usefully with the duck investigations of the Victorian Department of Fisheries and Game.

The initiation of the breeding studies coincided with an almost complete failure of the breeding season in the Riverina. This was disappointing but nevertheless enabled some very worth-while observations to be made.

The duck food studies, based on analysis of stomach contents, have progressed to a stage when the feeding habits of the more important species, and their changes during the season, can be fairly clearly defined.

6. Ibis Investigations.

(Wildlife Survey Section.)

Work was confined last year principally to the upper Murray Valley and the Murrumbidgee Irrigation Areas. The widespread grasshopper plagues enabled information to be obtained on the distribution and feeding habits of ibises in relation to these insects. Observations indicated that they and several other species of birds turn to this superabundant food supply when they happen to come in contact with it, but are by no means dependent on it. Food studies have revealed the following items of diet, listed in the approximate order of their abundance in the samples: crayfish, crickets, water beetles, spiders, grasshoppers, centipedes, caterpillars, fish, frogs, worms, snails, and leeches.

7. Bird Banding.

(Wildlife Survey Section.)

The organization of a national scheme for bird banding (previously referred to as "ringing") has now been completed in detail, the full range of standard bands is in hand, bands are already in use in the Section's own investigations, and arrangements to enroll co-operators and to publicize the scheme have been made.

8. Miscellaneous Investigations.

(Wildlife Survey Section.)

A number of minor investigations, involving the part-time—and often spare-time—attention of members of the Section's staff, have been initiated. These include: (i) research into the digestive physiology of the wallaby, *Setonyx brachyurus*, locally known as the Quokka (carried out in co-operation with the University of Western Australia, primarily to develop techniques which can later be applied to a similar study on the rabbit); (ii) a study of the brush-tailed possum, *Trichosurus vulpecula*, in the Canberra area which is providing data on population numbers, movements, breeding season, and the growth of the young; (iii) an investigation of the incubation of the mound building mallee hen, *Leipoa ocellata* (a paper presenting the results created great interest when read at a recent International Ornithological Congress held in Switzerland); and (iv) work on the starling, *Sturnus vulgaris*, carried out in the main to provide the basis for advice to bodies (including the Government of Fiji) desirous of taking action against the bird as a pest.

XI. UNDERDEVELOPED REGIONS.

1. General.

The normal processes of exploration and pioneer occupation have resulted in the rural settlement of most accessible and easily developed parts of Australia. There are, however, large portions of the continent and the Territories which are underdeveloped or only very sparsely occupied, by reason of low rainfall, poor soils, sparse pastures, inadequate water, and great distances from centres of dense population.

It is essential to understand the problems of these areas and where possible to solve them, so that either new developments can take place or the present level of production can be protected from unwise exploitation.

The development of northern Australia in particular has been slow in comparison with that of the southern and eastern States. Over 100 years have elapsed since the first settlements in the north, yet vast areas remain unproductive and are still only sparsely populated. In 1946 the Governments of the Commonwealth, Queensland, and Western Australia founded the Northern Australia Development Committee with the object of formulating a policy of development for northern Australia. The former Council for Scientific and Industrial Research was requested to initiate a series of land surveys of underdeveloped regions in order that this development potential might be more accurately assessed. In consequence, the Northern Australia Regional Survey established later as the Organization's Land Research and Regional Survey Section, was organized to conduct these regional surveys.

Whilst the work of the Land Research and Regional Survey Section is thus concerned with the sparsely populated arid and semi-arid regions of the continent, much complementary work is carried out by other Divisions of the Organization on the development of low-producing areas in the less isolated regions. The Division of Biochemistry and General Nutrition is investigating problems of plant and animal nutrition on the Coonalpyn Downs in South Australia (*see* Chapter III., Section 11), the Plant and Soils Laboratory is studying the wallum country in eastern Queensland (*see* Chapter III., Section 21), and the Division of Soils is making soil surveys throughout the Commonwealth (*see* Chapter II.). (Allied work is also carried out by the Division of Plant Industry on plant and pasture ecology at Trangie, New South Wales, south-western Queensland, and elsewhere (*see* Chapter III.).

Land Research and Regional Survey Section.—This Section has its head-quarters at Canberra and field stations at Katherine, Northern Territory, Ivanhoe (Kimberley, Western Australia), and Alice Springs. The Section is concerned with: (1) the survey and mapping of large underdeveloped regions and the primary assessment of land-use potential; (2) research into problems of agricultural and pastoral development in selected portions of these regions; (3) climatological studies; and (4) research into land-use problems of the arid and semi-arid zone of central Australia.

During the year the headquarters staff of the Section moved into a new building at Canberra.

The Officer-in-Charge of the Section attended the F.A.O. International Rice Commission's Meeting of Working Parties in Bangkok in September, 1953, as Australian delegate. He has since been nominated as permanent liaison officer between the Working Party on Fertilizers of the International Rice Commission and technical workers in Australia.

A large portion of the underdeveloped areas in Australia lie within arid and semi-arid regions. In order that the limited research resources available in Australia for problems of these regions may be used to the best advantage the Officer-in-Charge of the Section has been appointed by the Commonwealth Scientific and Industrial Research Organization as Liaison Officer for Arid Zone Research in Australia. This officer is also a corresponding member of the U.N.E.S.C.O. panel on Arid Zone Biology.

2. Regional Surveys.

(Land Research and Regional Survey Section.)

The two regional survey units of the Section continued to operate, one on the mainland of Australia and one in the Territories of Papua and New Guinea.

The main function of each unit is to classify and map the lands according to surface characteristics of importance in the determination of land-use potential. The second is to make the best possible assessment of the possibilities of land use, together with the estimates of areas of each type of country mapped. The surveys provide a basis of facts necessary for the formulation of policies concerning land development or conservation.

(*a*) *Australian Mainland Survey Unit.* (i) *Leichhardt-Gilbert Area.*—The main efforts of the Unit have been concentrated in this area (previously referred to as the Gulf Region) where the second season of field work is now in progress. It covers an area of about 110,000 square miles. The team returned from the first season's field work in October, 1953, and has since proceeded with the examination and interpretation of aerial photographs, which has led to the production of an interim map.

In February, 1954, a botanical collecting trip during the wet season was made within the area. A large collection of grasses and herbs, usually in a dead condition at the time of year when surveys are made, was obtained and the specimens have since been identified and distributed to other herbaria.

(ii) *Georgina River Area.*—Late in 1953 a botanist was sent to this area in response to urgent representations by the Animal Industry Branch of the Northern Territory Administration, which was investigating a poison plant problem then causing serious stock losses. Preliminary investigations were made and further work is planned with a more complete team at the conclusion of the field work in the Leichhardt-Gilbert area.

(iii) *North Kimberley Area.*—During the year the Section undertook the interpretation of aerial photographs and production of a land type map as a preliminary to a survey to be undertaken in this area by the Western Australian Government. The Section will attach two officers to this survey for a period of about one month in order to make a more complete botanical, soil, and land classification assessment.

(*b*) *Papua-New Guinea Survey Unit.*—During the year the first survey by the New Guinea Unit was made in the Buna-Kokoda area in the Northern Division of Papua.

This survey was largely experimental and principles developed in northern Australia had to be adapted to the different conditions. Nearly all the traverses had to be made on foot and this resulted in the investigations being more intensive than those of the mainland unit. To extrapolate the data obtained on traverses and also for proper orientation in the heavily timbered country recent aerial photographs of good quality have been found necessary. The field work was conducted using photographs taken early in 1951. Arrangements have been made to have new aerial photographs of the whole area taken.

For ease of movement and simplicity of transport in areas without roads and tracks it has been found imperative to keep the team as small as possible and the equipment very compact and light. The dense tropical vegetation, a great part of which has never been identified, presents special problems in its study and classification.

The survey examined the fertile slopes and alluvial plains of the Mount Lamington volcano, the rugged country of the extinct Hydrographer Range volcano, the low-lying flood plains of the Kumusi and Opi Rivers and the almost impenetrable peat swamps along these rivers, the volcanics of the Douglas Harbour plateau and the foothills of the Ajura-Kiljala Range, and the fertile Yodda valley between the Ajura-Kiljala and Owen Stanley Ranges.

The Yodda valley and the Mount Lamington country have promising and varied agricultural possibilities and large portions of the Kumusi-Opi River flood plains have potentialities for rice-growing. The other parts mentioned above have little or no value for regional development.

Provisional maps of the Kumusi River-Oro Bay portion of the area have been prepared, showing the geomorphological units, soil associations, vegetation types, and land systems, and an interim report has been prepared. Final accurate maps of the whole area will be prepared when the new aerial photographs are available.

(*c*) *Nauru.*—At the request of the Department of Territories two officers of the Section visited Nauru Island in November. As the rock phosphate deposits will eventually become exhausted it was necessary to investigate the possibility of other means of livelihood for the Nauruan people. The aim of the visit was to assess in the field both commercial and subsistence potentialities, to indicate the most suitable production systems, and to investigate the possibilities of reclaiming the worked-out phosphate lands.

The potentialities are seriously limited by the small area of suitable land, the infertility of the soils, and the irregularity of rainfall. Conditions on the island would seem to favour varied crop production on small individual plots rather than large-scale operations. There appears to be no economically justifiable possibility for reclaiming the old phosphate lands.

An unpublished report on the survey has been prepared.

3. Agricultural Research in North Australia.

(Land Research and Regional Survey Section.)

(*a*) *Katherine Research Station.*—In addition to research by the Land Research and Regional Survey Section into problems of dryland agriculture, the work of this station includes a programme of testing plant introductions and investigations into the possibilities of tobacco growing conducted by the Division of Plant Industry (*see* Chapter III., Section 8).

(i) *Crops.*—Rainfall for the season was characterized by heavy falls at the beginning and the end of the season, with frequent droughts between. There were in fact five breaks, varying from 14 to 30 days of hot dry conditions. These droughts adversely affected crop production, and damage was accentuated by the heavy rains at the end of the season.

Yields of individual crops fluctuated markedly between the different experiments, but the better yields were well up to average. Thus peanuts and sorghum both gave yields in the region of 2,000 lb./acre, whilst cotton exceeded 1,000 lb./acre (seed cotton). Sorghum appeared to suffer most from the recurrent droughts, and the grain harvested is small and pinched. It has been observed in previous years that the size of grain produced at Katherine is small, and yields appear to be related to grain size rather than to the number of grains.

Sunflowers reacted severely to the variable weather, but in spite of this justify further examination. Trials with safflower and maize showed that these crops were not suited to the region.

(ii) *Fertilizers.*—Work is concentrated on the effects of phosphate, and on the relative merits of superphosphate and rock phosphate. Although the soils are neutral in pH, rock phosphate is showing promising responses. The marked residual effects of superphosphate noted in previous years is being examined.

(iii) *Soil Moisture Studies.*—Difficulties in establishing crops have directed attention to moisture studies in the upper layers of soil. The top two inches shows a rapid rate of drying, and also a marked diurnal variation in moisture content which may have a deterrent effect on seed germination. It would appear necessary to plant seed below this zone for safety. This cannot be done with small seeds such as grasses, and attempts are being made to reduce germination difficulties by sowing such seed into a nurse crop.

(iv) *Cultivation and Tillage Practices.*—The importance of preventing surface seals through rain has again been evident. It was earlier believed that these seals functioned largely by preventing the penetration of rainfall into the soil, but further work has indicated that aeration may play a very important role.

Weeds, which were a relatively unimportant factor in the early days of the station, are annually assuming increasing importance. Improved general levels of fertility would appear to favour the gramineous weeds. The most troublesome weed on the station is the black or giant pigweed (*Trianthema* sp.).

(v) *Disease.*—Crops during the present season have been mainly free from disease. The drought-induced "charcoal rot", which severely affected last year's sorghum did not cause damage to this crop this season. The only crops affected to any marked extent were those of *Phaseolus* spp. *P. aureus* appears to be much less susceptible to drought-induced disease than *P. mungo* or *P. acutifolius.*

(vi) *Native Pastures.*—Studies on the composition of the native pastures in relation to climatic variations and to grazing have shown that it is the perennial species which were adversely affected both by drought and by grazing. The yield of annuals remains in the region of 100-150 lb. dry matter/acre. There has been a marked recovery of perennials in the current season, and total pasture yields are of the order of 1,200-1,500 lb./acre.

Factors governing the introduction of *Cenchrus* spp. and *Stylosanthes sundaica* (Townsville lucerne) into native pastures are being investigated. Evidence available suggests that establishment can be obtained only in very favoured localities.

(vii) *Sown Pastures.*—Survival has been adopted as the first criterion for preselection of grasses. An experiment is now in progress on the effect of differences in stand density and in fertility level on production in a group of selected grasses.

Experience with pure swards of grass has shown tha although reasonable production may be expected in th year of establishment, succeeding years are characterized by marked deterioration. It is believed that thi is associated mainly with a deficient nitrogen supply Attempts are being made to remedy this situation wit the aid of legumes and nitrogenous fertilizers. Result with mixed grass-legume pastures have not bee promising so far.

Townsville lucerne is showing promise when grow in pure stands. Yields of dry matter approaching tons/acre have been obtained, with a protein conten almost three times that of the dry natural pastures Supplementary feeding experiments with Townsvill lucerne are now in progress.

(*b*) *Kimberley Research Station.*—(i) *Crops.*—*Sugarcane.*—An encouraging feature is the success o earlier plantings and of ratoon crops. A first ratoo crop of nine varieties cut at thirteen months average 27-29 tons/acre, almost 3 tons/acre better than th plant crop at ten months. The leading variety, Pindar gave 39.5 tons/acre and a total of 74.5 tons for the tw years. Hand refractometer tests and actual suga determinations have both indicated very satisfactor sugar contents in these canes. Plantings made durin April to June last, in a time of planting trial, hav grown particularly well, and should give good yield when the canes are cut at 13-14 months.

Rice.—The more promising selections from over 20 varieties introduced from tropical and subtropica sources have again been tested along with commercia varieties from the United States of America and fro the Murrumbidgee Irrigation Areas. It has bee confirmed that these latter strains are not adapted fo summer growth in the Kimberleys, and that tropica varieties from Malaya, Burma, East Africa, and Indonesia appear well adapted. Good yields have bee obtained with multiplication plots of some of these tropical varieties.

Safflower.—Yields in the past season were below those obtained in previous seasons. Fertility factors related to the previous cropping of the soil are believed largely responsible. Time and soil factors may exclude this crop from a successful short rotation with the long-term varieties of swamp rice.

Other Crops.—A dry season (winter) irrigated crop of Kondut wheat, mechanically harvested 107 days after brairding, gave a yield of 34 bushels/acre. A wet season crop of peanuts and a dry season crop of sunflowers gave only moderate yields. An appraisal by commercial processers of the various varieties of peanuts under trial has shown that only one is in any way comparable with the standard Virginia Bunch for confectionery purposes. Sunflower varieties are being selected for uniformity of height and maturity and for non-shattering heads. Further small trials with the fibres kenaf, roselle, jute, and cotton were made. The standard varieties of cotton from Queensland were superior to the introductions, but yields were considerably reduced by boll pests, despite rigorous spraying and dusting schedules. Small plots of tobacco grown on the levee showed considerable promise.

(ii) *Fertilizer Experiments.*—It is becoming clear that after an initial phosphorus deficiency has been overcome, nitrogen is the most important limiting factor in the growth of sugar cane and grasses. With sugar cane, the ratoon crop appears to require more than the plant crop. Pastures respond well to additions of nitrogen, but the responses are ephemeral. Rice appears to require regular supplies of both phosphates and nitrogen.

(iii) *Irrigation.*—Comparing 12 and 24 day watering intervals with dry season crops of safflower and sorghum, the shorter interval gave approximately 20 per cent. higher yield. The water requirement of rice (including rainfall) has been found to be 75-80 acre-nch.

(iv) *Diseases.*—The main crops, sugar cane and rice, emained remarkably free from diseases. Peanuts were ess troubled by crown rot than usual, a consequence scribed to the maintenance of an adequate soil noisture level. Many kenaf plants showed symptoms f a virus disease.

(v) *Pests.*—A rice stem borer, identified as *Schoenobius chrysorrhoa* Zeller, has caused significant lamage to the crop. Contrary to previous experience, he attack began at a very early stage of plant growth. Grasshoppers reached plague proportions and did considerable damage to almost all crops, as a continued nflux of hoppers from surrounding areas hampered ontrol.

(vi) *Pastures.*—After three years' establishment nd two and a half years' intermittent grazing, pasture grasses appear to be stabilizing at a low level of productivity. Guinea grass and *Andropogon gayanus* are he most productive of the grasses under grazing treatment. *Clitoria ternatea* remains the only legume howing any promise in pastures on the clay soils, but t is not nearly so active in winter as in summer. It benefits the taller grasses, resulting in more and greener grass, but this effect is much less marked with he shorter grasses.

4. Climatology.

(Land Research and Regional Survey Section.)

During the year the climatology unit has continued o provide general climatic information to the survey nd agronomic units of the Section. Reports on the climates of the Leichardt-Gilbert area and the Buna-Kokoda area have been prepared. A detailed study of the climate at Ivanhoe, Western Australia (near he Kimberley Research Station) which will have lirect application to the research programme at Kimberley has also been commenced.

Further studies on the moisture characteristics of soils from the aspect of water availability for plant growth have been made with the collaboration of the Division of Soils. The narrow available moisture range of Katherine soils has been largely attributable o the kaolinitic nature of the clay fraction. Soils with similar characteristics are widespread in monsoonal Australia, and it is probable that the feature of a narrow available moisture range will likewise be widely distributed. This is currently under investigation. A further study at headquarters is an examination of the potentialities of a portable capacitance soil noisture meter designed in the Division of Plant Industry.

One of the more important projects proceeding at Katherine and Kimberley in collaboration with officers stationed at these centres concerns the extent of moisture losses from fallow soils during the dry season. This work is being spread over two years to examine the relative losses from soils which commence the dry season with moisture levels at approximately field capacity and those which are at approximately the permanent wilting percentage. A further study at Katherine is being made to follow changes in soil moisture status throughout the year under an area of natural pastures. At Kimberley studies on water use by sugar cane have been continued.

From experimental results already available on rates of water usage by various plants, investigations into the development of better climatic indices are proceeding. The main emphasis in this work is on the decreased rates of transpiration which obtain when soil moisture levels are depleted and moisture becomes less available to plants, rather than on the maximum transpiration rates which occur when soil moisture is freely available.

5. Arid Zone Research.

(Land Research and Regional Survey Section.)

The arid and semi-arid zones of Australia support large numbers of sheep and cattle even though the rate of stocking per unit area is low. It is of importance to maintain these areas at as high a productive level as possible and to raise this where practicable.

An officer has been stationed at Alice Springs since December, 1953. The main fields of investigations at this centre are: (1) ecology of native pastures with special attention to their management and maintenance under grazing; (2) ecology of introduced species in arid areas in relation to the possible modification and improvement of native plant communities. It is intended that this investigation will eventually be extended to cover the whole transect from Alice Springs to Darwin in which a wide range of climatic and edaphic environments occurs.

A reconnaissance survey of the native vegetation of the Alice Springs area has been commenced in the pastoral districts south of the MacDonnell Ranges and west of the main Adelaide-road. This is being extended to the Burt Plain, north of the ranges.

XII. FISHERIES.

1. General.

The acquatic resources of Australia, including whales, the more important commercial fish, crustacea and shellfish, and seaweeds, require study to ensure their economic use and, where necessary, their management to prevent depletion of stocks. Fundamental to this study is an examination of the environment to ascertain the variations in oceanographic and estuarine conditions which affect organic productivity and are to a large extent responsible for fluctuations in fish occurrences. Through its Division of Fisheries the Organization provides facilities for these studies.

Division of Fisheries.—The Division of Fisheries is concerned with research into the important aquatic resources of Australia. This research may be considered under the following headings:—

(*a*) the study of the biology of whales and the more important of the commercial fish, crustacea, and molluscs;

(*b*) the study of the oceanic, estuarine, and fresh-water environments in which fish occur.

During the year the studies have again been restricted to coastal waters because the Division has only two small research vessels. Consideration is being given to the provision of a trawler type oceanographic vessel to extend the work seawards.

The head-quarters of the Division is at Cronulla, New South Wales, and during the year teams also operated at Thursday Island, Queensland; Melbourne, Victoria; Hobart, Tasmania; and Perth, Western Australia. At the end of the year the Division withdrew its officers from Dunwich Research Station on Stradbroke Island, Queensland, on completion of the greater portion of local studies there.

During the year four officers made overseas visits and shared Divisional representation at the Copenhagen meeting of the International Council for the Exploration of the Sea, the International Limnological Congress at Cambridge University, the Pacific Science Congress and a pre-sessional Conference arranged by U.N.E.S.C.O. at Manila in the Philippines, to discuss an Institution of Oceanography in the Indo-Pacific area, a Conference on Marine Corrosion at Berkeley, and a Conference on Bioluminescence at Asilomar, California. A six-months' visit by one officer to Scripps Institute, La Jolla, was made possible by a Rockefeller grant. An officer also visited the Honolulu laboratory of the Pacific Oceanic Fisheries Investigations of the United States Fish and Wildlife Service, and participated in a tuna survey in equatorial waters.

Thanks are due to the Universities of Western Australia and Sydney for laboratory accommodation, to the Universities of Adelaide, Queensland, and Sydney for ready help, to all State Departments of Fisheries for general co-operation, and to the Western Australian Department of Fisheries for permission to share a recently-acquired field station on Rottnest Island; also to the Tasmanian Salmon and Freshwater Fisheries Commission and the Mount Field National Park Board for assistance with trout investigations in Tasmania.

The assistance given by Whale Products Pty. Ltd., the Australian Whaling Commission, the Norwest Whaling Co., and Whale Industries Ltd. is gratefully acknowledged. Thanks are also due to the Royal Australian Navy and to Huddart Parker Ltd. for assistance with the collection of sea-water samples.

2. OPERATIONS OF RESEARCH VESSELS.

(Division of Fisheries.)

(*a*) F.R.V. *Derwent Hunter*.—Four cruises from the home port of Hobart were made. Preliminary results of the surveys made are summarized elsewhere in this Report.

(*b*) F.R.V. *Gahleru*.—The F.R.V. *Gahleru* completed twelve short cruises during 140 days at sea.

3. WHALING.

(Division of Fisheries.)

The proportion of female humpback whales in the catch at Point Cloates station, Western Australia, rose from 46.7 per cent. in 1952 to 48.2 per cent. in 1953; and at Tangalooma, from 25.1 per cent. in 1952, to 27.3 per cent. in 1953. Measurements of mature whales at Point Cloates indicated that sexual maturity is reached at 36 ft. 9 in. in males and 38 ft. 6 in. in females. At Point Cloates a female humpback in the early stages of lactation, together with its new-born calf and a young female 31 ft. 4 in. in length, were taken by special permission for scientific purposes. An important observation made was that the mature female had ovulated again shortly after giving birth to its calf.

At Tangalooma station on Moreton Island, Queensland, a close study of the ovarian cycle was continued and many sample sections of corpora lutea were preserved. A strong correlation was noted between the two types of corpora lutea and the state of pregnancy and non-pregnancy; and a further nine early embryos ranging in size from $\frac{1}{4}$ to $\frac{3}{4}$ in. were obtained.

Aerial observations made on the Western Australian coast on the direction of migration of about 800 humpback whales, and on the presence of new-born calves, gave similar results to those recorded in 1952. Two whale marks were recovered during the season, one from a humpback tagged in 1936 in position 60°01′S., 80°55′E. and recovered at Point Cloates; the other from a humpback tagged on the central New South Wales coast on July 7, 1953, and recovered at Tangalooma six days later.

4. SEA FISHERIES.

(Division of Fisheries.)

(*a*) *Barracouta* (Thyrsites atun).—The year 1952-53 saw a continuation of the adverse fluctuation of the previous two years in the barracouta population of Bass Strait, and a return to normal (after the decline which occurred in 1951-52 only) in the availability of the population of eastern Tasmania.

Barracouta prefer waters at 13-18° C. and generally disappear from an area when it becomes colder (e.g., Bass Strait and Tasmania in winter) or warmer (e.g., New South Wales in summer).

An attempt was made to check a hypothesis that the barracouta of the Bass Strait and eastern Tasmanian populations pass the winter in the warmer waters east of Bass Strait, but it was apparent that trawling would be needed to reveal the true extent of barracouta occurrences in this area.

Work continued on the distribution and growth of immature barracouta and on the seasonal cycle of feeding and growth in adults.

(*b*) *School Shark* (Galeorhinus australis) and *Gummy Shark* (Emissola antarctica).—The investigation of school shark is being concluded. Recoveries of tagged sharks continue to confirm deductions about the slow rate of growth and widespread wanderings of this species. Altogether 270 tags have been returned, including 14 showing migration to various South Australian waters. The widespread movements of tagged sharks have proved conclusively the existence of a single stock of school sharks in the waters of South Australia, Victoria, Tasmania, and New South Wales.

The overall migration pattern determined from tagging and fishing shows that the main body of the stock is dispersed throughout the waters of the four States; but at the approach of winter, when the inshore waters of Victoria and Tasmania begin to cool, the majority of sharks there tend to move either northwards towards the warmer waters of New South Wales and South Australia or out to the edge of the continental shelf. There is a leisurely return southwards and inshore again during the late spring months of the year.

Most juveniles born in the sheltered bays and estuaries remain there until the late autumn before moving to the adjacent deeper waters. They return inshore to the estuaries and bays again during the late spring. This inshore phase of their lives lasts about three years, after which they leave to enter the stock in the open waters where they are fished commercially.

Two hundred and fifty-five gummy shark were tagged during the year.

(*c*) *Demersal Fish of the Continental Slope*.—Deep-sea longlining was continued periodically in south-eastern waters. There is an indication of a winter migration into deeper waters, this being most apparent in the movement of *Hyperoglyphe porosa*. Though the records of gonad stages are incomplete it is apparent that *Hyperoglyphe porosa* and *Mora mora* are summer and winter spawners respectively; no clear evidence is available for *Genypterus blacodes*.

(*d*) *Tuna*.—A divisional officer spent three months with the Pacific Oceanic Fishery Investigation Organization at Hololulu, studying its investigations into all phases of tuna biology and tuna fishery development. Using knowledge gained, a first cruise by an Australian research vessel in oceanic waters was planned and took place in February, 1954.

The 1953-54 tuna season on the southern coast of New South Wales was the most successful since the inauguration of the tuna industry. The live-bait and pole method of fishing as carried out by four boats produced 50 per cent. of the catch, whilst 50 trolling boats accounted for the remainder.

(*e*) *Australian Salmon* (Arripis trutta).—A detailed histological study of the reproductive cycle of the western sub-species of the Australian salmon has been continued, and already indicates that reports of large spawning fish in South Australia probably refer only mature male fish; mature females have not been und and there may be no effective spawning in this ea.

A comparison of the gonads of the Western Aus-alian and South Australian fish at the end of autumn ows similar degenerative changes in both groups f fish. An examination of the length frequency data f the so-called "large" fish in South Australia ndicates that they are of similar size to the smaller ge-groups of the Western Australian commercial shery. A total of 4,000 salmon have now been tagged n South Australia and from these 175 tags have been ecovered in local waters. In Western Australia 150 almon were tagged to confirm the annual spawning ovement, and two useful recoveries were obtained.

(*f*) *Ruff* (Arripis georgianus).—Tagging results to ate indicate that the behaviour of this closely related pecies is identical with that of the western sub-species f Australian salmon, and have confirmed that there s a single homogeneous population extending from Vestern to South Australia. Of 1,200 fish released in 952 in South Australia, nine recoveries were obtained n Western Australia. During 1953-54, 4,600 fish vere tagged in South Australia and further tagging vas done at Bremer Bay and Cheyne Beach in Western ustralia just before the spawning season. Several ecoveries from these releases indicated that fish moved o the Fremantle area which is considered to be the pawning centre.

(*g*) *Trawl Fish.*—(i) *New South Wales.*—Investiga-ions have continued to centre around the analysis of vailable catch and effort statistics and the routine ampling carried out in the Sydney Fish Market.

For the tiger flathead (*Neoplatycephalus richard-oni*) the aim has been to prepare results for integration nd comparison with past data. During the last four o five years there appears to have been a trend towards he handling of a decreasing percentage of larger fish 35 cm. and over) and an increasing percentage of maller fish (below 35 cm.).

In conjunction with the New South Wales Fisheries ranch and with the co-operation of a number of anish seiner owners, preliminary tests were made on he escape of tiger flathead from the cod-end of a anish seine net. The tests involved the use of overed cod-ends. The results indicate that a 3¼-in. esh in the cod-end of Danish seine gear would act as a aving device by allowing the escape of a large percen-age of undersized fish. Such a cod-end gives a 50 er cent. selection point very close to the existing New outh Wales minimum legal length of 33-cm. (13-in.). team trawling companies declined to co-operate in aking similar tests with otter trawl gear.

One hundred and fourteen tiger flathead were tagged ff Ulladulla in March, 1954. To date no return is ecorded.

Data on the morwong (*Nemadactylus macropterus*) nd nannygai (*Trachichthodes affinis*) continue to cumulate and await analysis.

(ii) *Victoria.*—The fishery by seine net depends ainly on tiger flathead. Some routine sampling has een done in the field and at the Sydney Market.

A tagging programme was initiated in August, 1953, nd 626 tiger flathead have been tagged and released ff Lakes Entrance, but few returns are yet to hand.

(*h*) *Pilchard* (Sardinops neopilchardus).—Com-ercial interest in pilchard fishing in Western Aus-ralia has diminished because of the low effective emand for the fish. In New South Wales waters fforts were made to check a hypothesis that pilchards re abundant below the surface, and sufficiently fat to e profitably reduced into oil and fish meal, in the ummer months. Results obtained in January, 1954, in the Port Stephens-Newcastle area were highly satisfactory. Although shoals were not seen at the surface they were readily detected in abundance by echo-sounding, and all of the large samples taken by drift net consisted of large fat fish. Oil content ranged from 11 to 17 per cent. by weight of raw fish (compared with 1-5 per cent. in winter) which would permit of profitable reduction if sufficiently large and regular catches could be made.

5. ESTUARINE FISH.

(Division of Fisheries.)

(*a*) *Lake Macquarie (New South Wales) Survey.*—Estuarine fish studies in the past have been concerned with the biology of individual species. A study of a mixed fishery as a whole has been lacking. Such a study of the relative abundance of species and their interaction commenced during the year in conjunction with environmental studies on the hydrology, microbiology, and planktology of the lake. The study on the fish commenced in January, 1954. The first few months were occupied in construction of gear and the testing of methods. Full-scale work commenced in May. By tagging very large numbers of fish it is hoped to obtain a measure of the fishing rate as well as data on movements and growth. It is evident that school fish such as mullet and tailer are plentiful in the lake but ground fish are relatively scarce.

(*b*) *Mullet* (Mugil cephalus).—Mullet were tagged in Western Australia and Queensland during the first six months of the year and in South Australia during the summer of 1954. The hypothesis that large mullet move out of the south-western estuaries and move northward has been supported by the recapture at Geraldton, Western Australia, of several fish tagged in Leschenault and Peel Inlets. In Queensland, tagging was confined to the northern end of the mullet run to learn whether individuals make a return move southwards again after spawning. In South Australia, mullet were tagged in the north-western waters of the State to see whether the stock of this area are autonomous or connected with either the eastern or western stocks. A systematic review of the mullet (Mugilidae) of Australia indicates the presence of seventeen species referable to nine genera.

(*c*) *Barramundi* (Lates calcarifer).—One thousand barramundi were tagged along the Queensland coast between Gladstone and Proserpine, about half of them being rescued from drying water-holes and released in adjacent rivers. Many thousands of fish must be destroyed each year by being stranded in such water-holes after the flood season. Barramundi have been found in all the rivers and creeks north of Maryborough and along the Gulf coast. They appear to prefer slow-moving muddy waters and to be tolerant of high suspensions of silt, being taken only as far out as the mud line. Rate of growth studies are continuing.

(*d*) *Whitebait* (Lovettia seali).—The catch and effort records of the fishery of the northern Tasmanian population indicate that the availability of fish was fairly stable at a low level, approximately 20-25 per cent. of that of the best recorded year 1946, over the three seasons 1950, 1951, and 1952. It had been hoped that the closing of the fishery in 1949, following the depletion of the population which became evident in 1948, would have brought about some recovery. However, there were signs of recovery in the 1953 season and the season of 1954 will be watched with interest.

(*e*) *Fish Culture.*—Advice has been given to several persons seeking information on the culture of mullet and bream in estuarine lagoons. The Division is at present doing no active work on fish culture, because it was decided that the cost of salt- or brackish-water fish culture would be prohibitive with high Australian labour costs.

6. FRESHWATER FISHERIES.

(Division of Fisheries.)

(*a*) *Trout Investigations* (*Tasmania*).—This work is nearing completion as far as the collection of factual data and their interpretation in relation to the administration of the fishery are concerned.

Examination of collections of scales from various north-west rivers has provided evidence of a considerable degree of natural spawning.

In Lake Leake in June and July last year, 1,270 brown trout were examined at the spawning run, and during August and September 720 rainbow trout were studied. In addition, over 400 fish of both kinds were taken by gill-nets from May to September. The nets were set near the outlet of the lake and all fish taken were marked for future identification, the object being to discover what proportion of fish appeared in the run up the Snow River, and hence to get evidence as to the extent of spawning in the shores of the lake.

In Great Lake over 3,600 brown trout were taken in the Liawenee Canal from May to July, and 720 rainbows were taken during September and October. The condition of the fish in the lake remains relatively poor and confirmation has been obtained that growth ceases after fish spawning, although in the early years it is good. In an effort to discover how far this condition results from the fish being completely landlocked, a number of fish were transferred from this lake to the Derwent River and tagged. It is hoped to recover some of these fish in the Plenty River fish-trap, through which about 370 fish passed from April to July on the spawning run. A downstream fish-trap which is being installed should establish the extent of the success of natural spawning by taking young fish migrating to the river.

(*b*) *Freshwater Fish Culture* (*Tasmania*).—Sufficient information has been obtained from recaptured trout to show that growth has improved as a result of the enrichment of Lake Dobson. Zooplankton is still abundant and the spread of plants continues, although it is two and a half years since the lake was artificially fertilized.

The artificial lake near Deloraine has made possible the study of conditions in a body of water created by flooding the natural land surface. This will have application to the new bodies of water formed by the activities of the Hydro-electric Commission. Since it has been stocked with fish at a known rate, and can readily be drained, it will provide valuable information as to the rate of growth and natural mortality of fish in such a body of water.

It is intended to stock four dams as soon as practicable and, by retaining one as a control, to follow the growth of the fish under varying conditions, with and without the addition of fertilizer. The object of the work is to discover the most economical and practical method of stocking for farmers.

7. CRUSTACEA AND SHELLFISH INVESTIGATIONS.

(Division of Fisheries.)

(*a*) *Western Australian Crayfish*.—During 1953 the continuous fishing test of 1948 at the western reef of the Pelsart Group, Houtman's Abrolhos, was repeated. The total catches of the two tests were: males 2,878, females 2,162; and males 1,480, females 1,275. All the crayfish taken in 1953 were marked and released outside the test area. With several exceptions, recaptures indicated movements limited to 102 miles. The comparison of the results in the two years is being prepared for publication.

Length-weight studies were continued. To test the effect upon the density and growth rate of smaller crayfish of the absence of larger crayfish in a given area, a ground approximately 60 by 20 miles was opened to intensive fishing operations by the Western Australian Department of Fisheries during 1954. It will be closed during 1955 and resampled in 1956.

Monthly gonad sampling was commenced at fishing grounds between Geraldton and Hamelin Bay, and from these investigations it is hoped to determine whether spawning in this species is annual or biennial.

(*b*) *Prawns*.—Further surveys were carried out with promising results at Shark Bay, Exmouth Gulf, and Cockburn Sound, Western Australia, on board the State Department of Fisheries P.V. *Lancelin*.

Three species of large penaeid prawns occur in Western Australian coastal waters. *Penaeus latisulcatus*, the blue-back prawn (related to *Penaeus plebejus*, the king prawn of New South Wales), grows to 8 inches and occurs from Bunbury to Exmouth Gulf. *Penaeus esculentus*, the tiger prawn of New South Wales and Queensland, grows to 10 inches, and occurs from Shark Bay to Exmouth Gulf and beyond. *Penaeus merguiensis*, the pink prawn, grows to 8 inches, and occurs in Exmouth Gulf.

In addition several species of *Metapenaeus* (greasy-back prawns) occur in Western Australian coastal waters.

(*c*) *Oysters.—Sydney Rock Oyster* (Crassostrea commercialis).—During the year an officer of the Division visited oyster growing areas in Italy, France, Holland, Great Britain, and the United States of America. Advantage was taken of a visit to Paris to inspect Lamarck's types in the Paris Museum. As a result some uncertainty in the naming of Australian oysters has been removed. A taxonomic review reveals the presence of ten native and one imported species, referable to three genera.

(*d*) *Scallops*.—Diving investigations again indicated an area of concentration of marketable scallops; this area was subsequently worked for almost a month by the main scallop fleet of 40-50 boats, almost 100 tons of cleaned scallop meats (representing 9,000,000 scallops) being taken. Diving was also done on the western side of Freycinet Peninsula and scallop grounds were located. It was noted that numbers per square yard on this ground declined rapidly in depths greater than 7½-8 fathoms.

(*e*) *Pearlshell*.—The collection of biological data on *Pinctada maxima, P. margaritifera, P. vulgaris,* and *P. sugillata* was continued at the Thursday Island station.

The collection of spat of *P. maxima* is obviously essential if shell culture is to be established. Three very small specimens of *P. maxima* were found on culture cages in March and four small specimens on 2,000 older specimens brought up by divers of F.R.V. *Gahleru*. An investigation of the mainland grounds shows good quantities of 1+ and 2+ age groups, hence it must be concluded that 0+ age group have not been collected on the ground because they are invisible or otherwise unavailable to the divers. Further evidence on this subject will be sought.

P. maxima reaches full gonad maturity in November and December and spawns in January and February. *P. vulgaris* and *P. sugillata* spawn in April and there are indications of a minor spawning peak in August and September.

Experiments are being continued to determine the exact age at which sex change occurs and much work is being done on the histology of the gonad.

A series of 900 tagged *P. maxima* have been set out on the mainland ground. These will be collected after twelve months to determine growth rate under natural conditions. Artificial fertilization of gametes was ccomplished in *P. maxima* and *P. sugillata.* A small ercentage of the fertilized ova survived to the ciliated arval stage and one larva was obtained.

8. Ichthyology.

(Division of Fisheries.)

(*a*) *Reference Catalogue of Australasian Fish.*—The comprehensive catalogue which was started several years ago has been kept up to date and now covers more than 2,700 species. An index to photographic negatives has been incorporated into the cross-indexing system.

(*b*) *Handbook of Ceylon Fishes.*—As a project under the Colombo Plan, a comprehensive illustrated handbook on and key to the 850 recorded marine and freshwater species of Ceylon has been completed, and has been accepted by the Department of External Affairs for publication and distribution to the governments of the countries of South-east Asia.

(*c*) *Check-list of New Guinea Fish.*—This list, covering 1,312 species, is being prepared for publication.

The identification of the fish material collected in New Guinea waters by M.V. *Fairwind* during 1948 and 1949 has been continued. This will serve as a practical basis for the preparation of a handbook of the fishes of the area requested by the Department of Territories.

(*d*) *Fish Eggs and Larvae.*—As part of the programme of determining spawning seasons and breeding habits of fishes in Lake Macquarie, the eggs, larvae, and postlarvae have been sorted from plankton collections and many of the forms identified to species. Work has begun on the identification and description of the rich collections of fish larvae and postlarvae obtained in New Guinea by M.V. *Fairwind.*

9. Hydrology.

(Division of Fisheries.)

(*a*) *Oceanic Investigations.*—Surface-water sampling between Sydney and New Zealand from T.S.M.V. *Wanganella* was continued. A thermograph has now been fitted to this vessel and continuous temperature records are available for correlation with the salinity data.

F.R.V. *Derwent Hunter* carried out two major oceanographical cruises. In February, 1954, an extensive survey of the south-western Tasman Sea demonstrated clearly the path of the east Australian current in this region and the continuity between southern Tasmanian waters and the deep Tasman Sea waters below the 12° isotherm. The presence of regions of divergence on either side of the east Australian current and the meandering characteristics of this current were other noteworthy features.

In March, 1954, a survey of Bass Strait and its aprpoaches was made. The previous data for this region seemed to indicate two principal water masses as being responsible for its fertility characteristics. Seasonal movements of water from the east in the summer and from the west in the winter were also postulated. The 1954 cruise results fully confirmed the existence of two water masses with very different fertility and temperature-salinity characteristics, one originating from the "Paddock" region of the south-western Tasman, the other from the south-west corner of the western approaches, this latter water mass being continuous around the southern Tasmanian coast with the eastern Tasmanian coastal waters. On the assumption of continuous mixing between these two water masses a fertility pattern was established for the period of the survey. This pattern fits well the distribution of zooplankton elements involved in the feeding of barracouta.

H.M.A.S. *Warrego* and *Barcoo* have contributed data from several surveys extending out into slope waters of the New South Wales coast.

(*b*) *Coastal Investigations.*—The regular sampling of coastal waters in New South Wales, Victoria, Tasmania, and south-western Australia was continued. It is now clear from recent data supplied by the New South Wales Weather Bureau that the long-term trends in hydrological properties of eastern Australian coastal waters during the period 1942-1953 have been accompanied by major changes in wind conditions over the Tasman Sea.

The seasonal variation in properties of the waters off Rottnest Island, south-western Australia, is due almost entirely to reversal of water-mass movement. There is no similarity between the factors responsible for the seasonal cycle at this station and a comparable one off the New South Wales coast.

(*c*) *Estuarine Investigations.*—The studies on the circulation of the Hawkesbury River estuary and on the assimilation of fresh water into its salt structure have received only minor attention during this year because of the concentration of effort on Lake Macquarie. However, it is clear that during a tidal cycle, although there is no reversal of flow at upper and lower levels, there is a net motion upstream on the right hand side facing upstream and the continuity of salt is maintained by this process rather than by a wedging of salt water along the whole bottom of the estuary. This same process could be responsible for the persistence of oysters or any other organisms with free-swimming larvae in such an estuary.

The studies on Lake Macquarie have had two primary aims: (i) the circulation pattern and the flushing rates; and (ii) the productivity and general hydrological characteristics of the waters and bottom deposits.

The circulation of this marine lake cannot be measured directly, as the velocities are far too low. To date it has only been possible to indicate in very broad terms the manner in which wind, quasi-tides, internal waves, and freshwater discharges affect the circulation. An indirect estimation of the rate at which nutrients are transported from the mouth of Dora Creek as a source along the median axes of the lake is dependent upon a more exact knowledge of the rate of discharge of such nutrients from the creek.

More recent surveys have paid particular attention to the hydrology and characteristics of the bottom deposits of Dora Creek. The creek consists of a series of ridges alternating with deep basins and the liberation of phosphates seems bound up with certain optimum conditions of chlorinity, pH, and oxidation-reduction potential in these basins. These conditions are only established at irregular intervals.

Nutrient levels and chlorophyll counts indicate a higher productivity for the lake than for marine-dominated estuaries of the New South Wales coast.

In Western Australia the mechanism of renewal of the bottom waters of the Swan River basin during the spring of each year has been studied. Under the extremely stratified conditions in this basin during the early spring period, progressive internal waves appear to move along density boundaries. Recently recording water-level gauges were installed at extremities of the basin, and the records from these will provide detailed information on the possible role of wind in the development of such waves and other circulation patterns in the Swan River basin. There is a difference in phase between the development and disappearance of phosphate and nitrate pulses in the deep basin waters, which are now being analysed for ammonium ion as a check on the possibility that under highly reducing conditions in the deep basin waters nitrates are reduced to ammonium ion.

(*d*) *Intertidal Region—Shell Point.*—The two main problems under consideration are: (i) the mechanism of subsurface transport of soluble nutrients, and (ii) the manner in which organic material developed in the mud surface can be made available as oyster food at various levels above the mud surface.

The first problem has involved studies of the subsurface circulation of water. The pressure fluctuations during a tidal cycle, as measured manometrically, indicate that the water movements in the intertidal mud are conditional by the tide, with various phase lags due to the degree of compactness of the mud.

The second problem has involved the development of sediment traps which must work efficiently in a region of fluctuating water-level and tremendous variation in turbulence. A satisfactory design has now been developed, and more recently it has been found that the nitrogen status of the sediment load can be correlated with the chlorinity condition in the upper 10 cm. of mud.

10. Plankton Investigations.

(Division of Fisheries.)

Papers are being prepared on the seasonal and long-period fluctuations of plankton associations observed in monthly collections made during the year at the following stations off the New South Wales coast:—Evans Head, Coff's Harbour, Port Macquarie, Botany Head, Ulladulla, and Eden. Two stations, one 50 m., one 100 m., are occupied weekly off Jibbon.

A survey of plankton in Lake Macquarie has been made each month.

Further attention is being paid to the geographical, seasonal, and bathymetric distribution of the euphausians of south-eastern Australian waters, where they are very important in the diet of barracouta, tuna, salmon, flathead, and other fish.

The results obtained on the combined hydrology-plankton-pelagic fish surveys of the F.R.V. *Derwent Hunter* in the western Tasman Sea (February, 1954) and Bass Strait (March, 1954) are of particular interest. On the Tasman Sea survey it was possible to distinguish two associations of euphausian species respectively north and south of lattitude 40° S., the southern one being richer in species and total numbers than the northern; the tuna taken on the cruise (mainly albacore, *Thunnus germo*) were feeding largely on one of the southern euphausian species, and all tuna but one were taken in the southern area. The most productive part of the whole region for euphausians, tuna, and other pelagic fish (as detected by eye at the surface, and by echo-sounding) was from the east coast of Tasmania to 50 miles offshore.

11. Other Investigations.

(Division of Fisheries.)

(*a*) *Fouling.*—Routine fouling observations were continued for the Royal Australian Navy and for certain of the Sydney power-houses.

(*b*) *Microbiology.*—The limits of the environment of some of the chief microbes active in estuarine mud were outlined by determining electrode potentials and hydrogen ion concentrations in this environment. Examination of a great many cultures yielded the outline for the natural milieu of sulphate-reducing and of sulphur-oxidizing (dehydrogenating) organisms. The work was continued, especially with purple and green sulphur bacteria and with green flagellates and blue-green algae. The first part of the work has been accepted for publication. The cytochromes in the various microbial groups mentioned above were studied. It was found possible to produce more than 1 oz. of various forms of bacteria and green flagellates. Hydrogenase-containing strains of sulphate-reducing bacteria were found to form organic sulphur compounds in organic media.

XIII. FOOD.

1. General.

The preservation of food is an increasingly important link between primary industry and the consumer market. There is a growing awareness of the part which science and technology can play in reducing wastage, improving quality, and generally raising the efficiency of Australia's food processing industries. The complex constitution of foodstuffs of all kinds, especially meat, dairy products, and fruits, calls for fundamental studies based on physics, chemistry, botany, and bacteriology to ensure the elimination of processing and storage conditions which tend to their deterioration. As a major food producing country situated far from the main food importing nations, and with its own population centres separated by long distances, Australia has a special interest in the preservation of foodstuffs during transport.

The Organization's work on food is undertaken chiefly within the Division of Food Preservation and Transport with its main laboratories at Homebush, New South Wales, and branch laboratories at Brisbane, Queensland (meat); West Gosford, New South Wales (citrus fruits); Eden, New South Wales (fish); Hobart, Tasmania (fish, apples, and berry fruits); and at the Botany and Biochemistry Departments, University of Sydney (plant physiology and physical chemistry). The work of the Division is described in Sections 2-11 of this Chapter. Work on the manufacture of dairy products is carried out by the Dairy Research Section at Fishermen's Bend in Victoria (*see* Section 13 of this Chapter). Co-operative investigations on wines are carried out in the Waite Agricultural Research Institute (*see* Section 12 of this Chapter).

Work on dried vine fruits is in progress at the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria (*see* Section 14 of this Chapter). The Organization's Central Experimental Workshops at Maribyrnong, Victoria, has designed and constructed equipment for the mechanical washing of dried fruits (*see* Section 15 of this Chapter).

Division of Food Preservation and Transport.—While considerable progress has been made in the co-operative investigations on beef at the Division's Brisbane laboratory, it is unlikely that methods for the elimination of "drip" from frozen and thawed beef will be found in the near future. It was hoped that methods of treatment which had been most promising with rabbits could be applied to beef cattle. The investigations have revealed, however, that there are some profound differences in the reactions of rabbit and beef muscles to various ante and post mortem treatments. The reasons for these differences are now being sought. Dr. R. A. Lawrie, who was seconded from the Low Temperature Research Station, Cambridge, to take a major part in this work, returned to England in June, 1954, after the completion of the first part of the programme. The work will be continued by an officer who has recently returned to Australia after a period of post-graduate training in muscle biochemistry in England.

Adjustment of the available water in foods has long been a valuable method of preservation, but there has hitherto been considerable paucity of information on its scientific basis. A major contribution has now been made through the definition of the precise water requirements of a number of strains of bacteria causing oilage or food poisoning. Predictions can now be ade of the amounts of water in various foods which ll permit the growth of these organisms.

At the request of the Australian Committee on nimal Production, the Division, with the help of e Agricultural Research Liaison Section, convened conference in July, 1953, on the science of bacon and m curing. At the request of the conference, a com-ittee is now examining several questions concerning ientific research and courses of technical education on ring.

The Division has continued to give assistance to a umber of State and Federal Government departments. or instance, at the request of the New South Wales epartment of Agriculture an investigation was con-ucted into the causes of an alleged high rate of eterioration of the bloom of lamb and mutton carcases repared at country meatworks and forwarded in the hilled condition to Sydney markets.

Assistance has also been given to several branches f the food industry, and these have expressed their ppreciation through many generous donations of noney, which has been mainly used to purchase cientific equipment.

2. PHYSICS.

(Division of Food Preservation and Transport.)

(*a*) *Rail Transport.*—Several sets of measurements of air leakage into two types of refrigerator car have been carried out and the results used to estimate: (*a*) the contribution of air leakage to the heat load on the cooling system, which is typically about 10 per cent. in the types of vehicle studied; (*b*) the risks of excessive accumulation of carbon dioxide in fruit cargoes; (*c*) the possibilities of maintaining a useful concentration of carbon dioxide during the transport of special meat cargoes. It was shown that loss of the water seals on the drains resulted in a large increase in the air leakage into moving cars.

(*b*) *Evaporation from Foodstuffs in Cold Storage.*—Work is continuing on the relation between the rate of evaporation from fruit and the relative humidity of the surrounding atmosphere at temperatures and humidities such as occur in cool stores.

Systematic study of the factors affecting evaporation from fruit packed in cases has been resumed. An experiment is in progress in a commercial store to determine the extent to which a rather high rate of forced air circulation may increase water loss by increasing air exchange between the inside of the case and the outside.

(*c*) *Effects of Various Features of the Design of a Cold Store and its Cooling System on Evaporation from Stored Goods.*—Theoretical analyses have been carried out, and measurements made in a commercial frozen meat store to provide means of checking the assumptions made. This work is continuing.

(*d*) *Canning Processes.*—(i) *Conduction Errors in Thermocouples and Their Effects on Experimental Determinations of Processes.* — Some equations developed by Professor J. C. Jaeger have been used for a preliminary theoretical analysis of this problem and the planning of experiments to determine the importance of these errors in practical process determinations.

(ii) *Effects of Headspace on Canning Processes.*—Work was completed on the effects of the thermal resistance of the headspace on the rate of heat penetration into solid packs. This work is being extended to find relatively simple methods of estimating equivalent processes for cans of different sizes which will be more accurate than those in use. Experiments with liquid packs have shown that this problem is more complex than might have been expected.

(*e*) *Performance of Cold Stores for Fruit.*—The accumulated data from previous work have been analysed further. Measurements are in progress in one store of a type not previously studied.

(*f*) *Water Relations.*—Further data have been collected on the relation between the water content of materials and the pressure of water vapour in equilibrium with them. Materials studied include dried vine fruits, silk protein, and some substances suitable for use as "in can" desiccants.

As it is desirable to confirm some of the results by an alternative method, more versatile equipment for weighing in closed spaces is being designed. It will be possible to deal with more samples simultaneously with the new equipment.

(*g*) *Colour Measurements.*—The development of apparatus required to make precise objective measurements of the colour of foodstuffs during processing and storage has been continued.

3. FOOD CHEMISTRY.

(Division of Food Preservation and Transport.)

(*a*) *Volatile Products of Apples.*—The organic volatile substances produced by fresh apples are concerned in the aroma and possibly also in the control of ripening. There is evidence of some relation between volatile substances and superficial scald, a functional disorder.

A number of lower alcohols, aldehydes, and acids, together with acetone and ethylene, have now been identified, and the effect of these volatiles on the development of superficial scald in stored Granny Smith apples is being investigated. Changes in the natural volatiles of the surface tissues are also being determined. Some slight effects on scald have been obtained, but none of the natural volatiles have yet been implicated. Tests for the presence of olefines higher than ethylene are being carried out.

(*b*) *Natural Coating of Apples.*—The studies on the natural lipid coating of apples are related to the physiological behaviour of stored fruit, as the natural coating is the main barrier to gaseous diffusion and hence influences the composition of the internal atmosphere. The chemical constitution of the oil and cutin fractions is being investigated.

The saturated acids of the oil fraction have been shown to be predominantly stearic and arachidic, with smaller amounts of palmitic and behenic. This identification has been facilitated by the development of a technique for separating hydroxamic acids by partition chromatography. This technique should also facilitate separation of the unsaturated acids. Some progress has been made with the separation of a more volatile fraction of the alcohols by partition chromatography of derivatives. Further chemical study has been made of the cutin fraction after purification with snail cellulase.

Wraps impregnated with mineral oil are effective in controlling superficial scald, but the mechanism of their action is unknown. It has been shown that during prolonged storage there is an interchange of lipid material between the natural coating and the wrap. The significance of this fact in relation to storage will be further investigated.

(*c*) *Determination of Organic Bromides in Air.*—Ethylene dibromide is used for fumigating citrus to destroy fruit fly infestation. The method for determination of ethylene dibromide and ethylene chlorobromide (an alternative fumigant) has been thoroughly tested.

(*d*) *Water-soluble Constituents of Fruit.*—These studies will provide basic knowledge required for investigating the reactions involved in the browning of dehydrated fruit. Much of the information being obtained is also of interest in other fields of work. The sugars in several types of fruit are being separated by means of chromatography on cellulose and charcoal columns. This work has revealed some components not found by paper chromatography.

The separation of organic acids by displacement chromatography, using columns of anion-exchange resins, has been studied further and over 20 different acids can now be separated. This method has been used to study the acids in apricots, peaches, pears, passionfruit, and oranges. In several fruits all the major acids and a number of minor acids have been isolated and identified. It was shown for the first time that quinic acid is a major acid in peaches.

A comparison of the sugars, amino acids, and carboxylic acids in orange juice did not reveal any striking differences between different rootstocks.

(*e*) *Chemical Reaction in Processed Foods.*—Freeze dried apricot and peach purées were equilibrated to approximately 20 per cent. moisture content to study browning reactions. Some qualitative changes, revealed by paper chromatography, occurred in the sugar and amino acid fractions after only a short period of storage at 25° C.

(*f*) *Physical Chemistry of Proteins.*—Studies in the denaturation of proteins and enzymes by urea, heat, and freezing have been continued. The general aim has been to study the process by following simultaneously the changes in several properties which are sensitive to different kinds of deformation of the protein. In particular, changes in sedimentation constant, solution viscosity increment and pH during the denaturation of ovalbumin, bovine plasma albumin, β-lactoglobulin, ribonuclease, and pepsin have been studied. Results obtained throw some light on discrepancies among the results of other workers in the field. An attempt is being made to assess the importance of sulphydryl and disulphide exchange reactions in protein aggregation phenomena.

(*g*) *Infra-red Spectroscopy.*—The instrument has been equipped with a new radiation detector and modifications made in the apparatus for freeing the spectrometer of atmospheric moisture and carbon dioxide. Studies have been carried out on the determination of the structure of limonin, the bitter principle of oranges, and related compounds. Measurements have been carried out for other laboratories, including filter transmission measurements for the Commonwealth Solar Laboratory.

(*h*) *Polarography.*—The recording D.C. polarograph which is being developed has been modified to permit of precise measurements of current down to 0.01 μA full-scale deflection. Equipment has been set up which makes it possible to measure the current over a short interval near the end of the life of the drop, rather than over the whole period.

The technique of derivative polarography, involving the superposition of a square wave of 10 c/s, has been applied to the measurement of cadmium and lead in various supporting electrolytes, in both the presence and absence of colloids.

The D.C. polarographic studies in metal complexes of amino acids and proteins have been furthered during the year by electrophoretic measurements. The mercury complexes of certain proteins containing sulphydryl groups are now being examined in an attempt to assess the available sulphydryl groups in proteins.

4. Microbiology of Foods.

(Division of Food Preservation and Transport.)

Studies of the important food-poisoning and food-spoilage micro-organisms have continued, particularly of their reactions to various factors in their environment. The results of such studies have a general validity which, as data accumulate, is becomin increasingly useful in a variety of processing an spoilage problems. In addition, there has continue a steady flow of small problems relating to the diagnosi and control of spoilage in various foods.

(*a*) Clostridium botulinum *Investigations.* — Wor on these important food-poisoning organisms has continued and an experimental study of some aspects o the physiology of ten type E strains has been complete Experiments on the water requirements for growth o several strains of types A and B are in progres Results so far show that the water requirements wi not be very different from these recently publishe for the *Salmonella* group.

(*b*) *Bacterial Spores.*—Studies of the formatio germination, and heat resistance of these resistan forms of bacterial life have been continued, particula attention having been given to the inhibition of germination by low concentrations of lipid materials. Th spores of several species differing widely in thei resistance to heat are being examined for propertie which might explain the observed differences in hea resistance, but no adequate explanation of the difference has yet been found. The Division of Industria Chemistry is collaborating in a study of the fin structure of different types of spores. An India research student of the New South Wales Universit of Technology is studying the relation between th resistance of spores to certain chemical disinfectan and their resistance to heat. Another Indian studen has recently completed a study of the heat resistanc of the spores of organisms causing spoilage in canne bananas.

(*c*) *Water Relations of Micro-organisms.*—Th water requirements for growth of fourteen foo poisoning strains of *Staphylococcus aureus* and c sixteen strains of *Salmonella* have been defined. On species of *Salmonella* has been studied in greater detai particularly the relation between the water requirements and the nutritional status of the medium. Som progress has been made in studies of the exchang of water and some solutes between the cells and th medium. The water requirements of five strains o *Pseudomonas* have been studied at 0, 10, and 30° The range of water activities permitting growth i not very different at these three temperatures.

(*d*) *Freeze Drying.*—Work on the preservation o bacterial cultures by drying from the frozen stat has been expanded. Several experiments designed t define the most suitable storage conditions have bee commenced and will continue for five years. Th importance of two environmental factors has alread been established. Other variables which have larg effects on survival during the actual drying proces have little or no effect on the rate of death durin storage. The construction of improved equipment t facilitate study of the drying process has bee commenced.

(*e*) *Spoilage of Meat.*—The exact circumstance leading to the occasional severe losses due to bon taint in beef have long remained obscure. The growt requirements of organisms isolated from spoiled hin quarters have been studied, and recently more spoile quarters were obtained for detailed examinatio Evidence that several types of bacteria may cause thi type of spoilage is accumulating.

5. Meat.

(Division of Food Preservation and Transport.)

(*a*) *Co-operative Investigations.*—(i) General— The officer seconded from the Low Temperatur Research Station, Cambridge, carried out a series o investigations designed to apply the results of th Cambridge studies on small animals to beef steers.

(ii) *Pre-rigor Freezing.* — It has been found mpossible to freeze an appreciable portion of a steer r cow carcass in the pre-rigor condition, as rates of reezing are too slow with the heavy steer carcasses, nd the more rapid freezing of cow carcasses is offset y the more rapid onset of rigor. Variation in rates f freezing and the introduction of a period of elevated emperature before thawing did not produce worthvhile changes in the extent of drip. An attempt to btain pre-rigor freezing is being made by using earlings and delaying the onset of rigor by complete nuscular relaxation before slaughter.

(iii) *Pre-slaughter Treatment of Animals.*—It has een found that many of the conceptions relating to the ffect of pre-slaughter exercise and starvation on rigor vhich were developed from investigations on small nimals are not applicable to beef steers, mainly owing o the large difference in the glycogen reserves. It as been found possible to alter the time of onset of igor considerably by injecting calcium and magnesium alts, relaxing drugs, and insulin, but only with insulin, vhere pronounced changes in ultimate pH were nduced, was any change in drip brought about. Naturally occurring changes in ultimate pH, with esulting changes in drip, have been noted as being ssociated with variation in excitability of the animals.

(*b*) *Chilled Beef Studies.*—These studies have shown hat apart from drip the only difference in favour of he chilled product is a slightly greater tenderness.

(*c*) *Airborne Contamination.*—The relationships of emperature and humidity to the death rates of airborne rganisms have been surveyed over a large range and he data provide a background for a study of the ffects of aerosol disinfectants.

(*d*) *Freezer Burn Studies.*—The study of freezer ourn in frozen offals in storage has been continued.

6. FISH.

(Division of Food Preservation and Transport.)

(*a*) *Crayfish Processing.*—Investigations have begun n the influence of the biological condition of whole Tasmanian crayfish, and of the methods of cooking, ooling, freezing, and thawing, on the body weight osses and on the palatability of the edible fish. An bnormal condition involving brown to black discoloraion of the livers and stomachs of some live crayfish as been investigated in co-operation with the Division f Fisheries.

(*b*) *Chemical Methods for Estimation of Spoilage.* —Work on the estimation of volatile bases in bacteriologically spoiled fish muscle and in canned fish and shark has been completed.

(*c*) *Spoilage in Prawns.*—Assessment of the chief sources of contamination of cooked prawns between ooking and marketing has continued. Cooking condiions necessary to prevent the subsequent development of "blackhead" in cooked prawns have been established.

(*d*) *Fish Canning.*—Processing studies on canning of tuna, shark, barracouta, abalone, crayfish, Tasmanian mud oysters, and Pacific oysters originally introduced from Japan have been carried out.

7. EGG INVESTIGATIONS.

(Division of Food Preservation and Transport.)

(*a*) *Pink Whites in Stored Eggs.*—Ingestion by fowls of plants of the family Malvaceae gives rise to a pink colour in the white of the eggs after storage. The technique of reversed phase partition chromatography is being used to isolate from these plants a minor constituent—a fatty acid—believed to cause this disorder. An acid with a constant melting point through several crystallizations has been obtained, and will be tested against fowls and eggs.

(*b*) *Effect of Additives on Egg-coating.*—With the object of improving the qualities of the paraffin oil used for coating eggs the effect of adding aluminium and magnesium stearates has been followed by means of internal quality changes in the eggs during storage.

Under cold storage conditions corresponding with normal commercial practice, there was no benefit in adding aluminium and magnesium stearates to the oil, except a slight reduction in the rate of water evaporation.

8. FRESH FRUIT AND VEGETABLE STORAGE AND TRANSPORT.

(Division of Food Preservation and Transport.)

(*a*) *General.*—In collaboration with the University of Sydney and the New South Wales Department of Agriculture, the Plant Physiological Research Unit is carrying out a programme of research both at Homebush and at the Citrus Wastage Research Laboratory, Gosford. Some work is also done in the Botany School, University of Melbourne. This large collaborative venture enables research to extend from academic problems concerned with the background knowledge on which fruit storage depends, to applied problems of improving storage quality and decreasing wastage.

(*b*) *Plant Physiology and Biochemistry.*—Work in collaboration with the Universities is principally in plant physiology and biochemistry, relating to the structure and function of plant cells which together make up the whole plant body. In recent years the investigation has been extended to include a study of the properties of the microscopic particles which occur within the cells. The particles have a quite definite structure and this has been studied, in collaboration with the Division of Industrial Chemistry, with the electron microscope. Chloroplasts, the green bodies of the cell, have been shown to have a definite and regular structure with a membrane, and the mitochondria, which are at the limit of resolution of the ordinary microscope, have been shown to have a membrane. These membranes play an important part in controlling the chemical reactions within the living cell and their properties are being studied in detail. Not only are these structures surrounded by a membrane but they also have definite metabolic activity by which they can change their internal composition and maintain differences from the surrounding medium.

Respiration studies have led to a hypothesis connecting the energy liberated by respiration with the energy-requiring processes in the cell, and this hypothesis has been used to interpret the sudden rise in respiration associated with the ripening of fruits. The hypothesis is being tested further by experiments on the maturation of peas, in which there is a particularly active synthetic process at a certain stage of maturation. The studies of these processes may have an important bearing on our knowledge of optimum maturity. Respiration and synthetic processes are connected by substances termed phosphate carriers, and recently methods have been developed for the analysis of these phosphate carriers under different conditions of synthesis. Experiments on respiratory enzymes of apple tissue are being continued.

Since earlier work has shown the relation of fruit size and cell number to influence the behaviour of apples of different sizes in store, some investigations have continued. Further comparisons have been made between Delicious apples grown in Australia and the same variety grown in America, where they seem to have more cells per fruit. The effects of blossom thinning have also been studied.

One of the most important constituents of all plant foods is sucrose and its mechanism of synthesis in higher plants has been obscure. Recent work has led to hypotheses for such a mechanism and this work is being continued with particular reference to the mechanism operating in peas.

Studies of the behaviour of citrus fruits have been handicapped by inadequate knowledge of their physiology and development. An attempt to study the morphological and physiological changes taking place during development has begun.

(*c*) *Technology.*—(i) *Best Conditions of Storage for Apples.*—Attempts are being made to find improved methods of storage for apples. Factors investigated in the past few years include the variability in storage behaviour in fruits from different parts of the orchard, the effects of different maturities and methods of judging maturity, and those of temperature in storage. Most of these investigations require observations over a number of seasons followed by statistical analysis. An extensive investigation of gas storage of apples, i.e., the method by which the oxygen and carbon dioxide content in the store are controlled to prolong storage life, has begun. Commercial interest in the possibility of gas storage for apples in Australia is increasing.

(ii) *Best Conditions of Storage for Pears.*—The effects of delay and rate of cooling of both Williams Bon Chrétien and Packham's Triumph pears have been investigated for several years. The results confirm the general conclusion that optimum maturity at picking, and cooling rapidly as soon as possible, are of great importance. Some investigations on the control of rotting in Winter Cole pears are also in progress.

(iii) *Control of Wastage in Citrus.*—The most important cause of wastage in oranges grown in the natural rainfall districts is green mould. Experiments have shown that a dip of sodium *o*-phenylphenate is the most effective method of reducing this mould. At first some difficulty was experienced in preventing these substances from injuring the skin of the fruit, but conditions have been worked out to overcome this injury and the method has been tried with most satisfactory results on a commercial scale. The method is more effective and less expensive than the previous dip treatment. Since dipping is not always practicable or desirable as a means of mould control, further experiments are also being done on control by the use of wraps impregnated with diphenyl.

The principal cause of wastage in stored lemons is the development of a fungus, causing stem end rot. This can be controlled by the use of 2,4-D or 2,4,5-T as a dip after harvest, and control is improved by appropriate field sprays during the growth of the fruit. Work on the best conditions of lemon storage has been continued.

In studying citrus wastage due to mould, quantitative methods are being developed for loading the fruit with a known inoculation of spores and for determining the spore load of fruit under natural conditions. This work is in collaboration with Dr. T. B. Kiely of the New South Wales Department of Agriculture.

Variations in treatments of trees in the orchard may have marked effects on the keeping quality of the orange. Storage behaviour of fruits from trees grown under different conditions on Farm Block 466, Griffith, New South Wales, are being studied in collaboration with the Irrigation Research Station.

(iv) *Potato Storage.*—An experiment was carried out to compare the storage behaviour of different varieties of potatoes and the effects of storage on the quality of the different varieties.

(v) *Control of Fruit Fly.*—Methods to kill fruit fly in harvested fruits have been developed. Since some of these methods have harmful effects on the keeping quality of some fruits, a study of the effects on a number of varieties was carried out.

9. CANNING AND FRUIT PRODUCTS.

(Division of Food Preservation and Transport.)

(*a*) *Vegetable Canning.*—An important contribution was made to the work on the short-term prediction of maturity of pea crops by extending investigations to crops grown in the United States. With the use of the maturometer and experimental techniques developed by this Division, the general developmental pattern of the varieties tested at Geneva (New York) was found to agree closely with that determined in Australia. The rate of maturation was faster than that of normal crops in this country, but excellent control of the optimal harvest time was obtained by slight modification of the prediction method.

Increased interest in the United States in the mechanical green bean harvester has made it imperative to define the optimal harvest time and to find some means of predicting it. Some general trends have been determined by a fourth field trial on green beans at Richmond, New South Wales, but it was concluded that work of a large-scale nature was essential. Participation in such a trial in America gave encouraging evidence of the value of the maturometer for prediction, when special precautions were taken in preparing the sample. Future investigations in Australia will be carried out on commercial crops of green beans by co-operative effort with a selected vegetable cannery.

Certain fundamental data are needed before proceeding with breeding work on canning tomatoes. A special trial has been designed to measure the variation in a number of factors which are important in the assessment of quality, and these data will be used in later trials as a basis for varietal comparison.

(*b*) *Fruit Canning.*—Previous indications that immature Trevatt and Moorpark apricots could be ripened artificially to give a canned product equal in quality to that from tree-ripened fruit were confirmed. A storage and ripening trial showed that Trevatt apricots can be stored successfully for four weeks at 32° F. prior to canning. This result was also obtained last season.

As in 1953, J. H. Hale freestone peaches picked immature and ripened artificially gave an excellent canned product. There are indications that trees of apricot and peach canning varieties may be completely stripped when the advanced fruit reaches the tree-ripe condition, and all fruit subsequently brought to desirable maturity by artificial ripening. This procedure would save harvest labour and minimize transit losses, but further investigation is required before it can be recommended.

Investigations of factors related to the quality of Tasmanian solid-pack apple have proceeded rapidly. The Division is now able to make recommendations on brine-holding and calcium-firming procedures, and the method of adding water to standardize headspace and reduce corrosion in the can.

Further data on berry fruits, needed for the specification of berry pulps, are being accumulated. Varietal trials and investigation of appropriate syrup strengths are continuing as part of a programme of quality improvement of canned berries.

(*c*) *Fruit Juices.*—Investigations on the occurrence of bitterness in canned orange juice have established that this bitterness is influenced mainly by the rootstock on which the trees are propagated and by the maturity of the fruit, but these influences are subject to regional and seasonal variations. Thus the effects of rootstock on the quality of Navel and Valencia orange juices appear to be more marked in the New South Wales coastal region than in the Murrumbidgee Irrigation Areas and the Murray Valley. The degree of bitterness in processed juices is directly related to the amount of the bitter principles, limonin, present in the peel of the orange. Chemical investigations on limonin are now being carried out in the Organic Chemistry Department, University of Sydney, under the direction of Professor A. J. Birch and encouraging progress has been made towards elucidating the structure of this complex substance.

(*d*) *Container Investigations.*—An acidified aqueous extract of beetroot tissue has been found to provide a reliable test standard for the measurement of corrosion resistance in lacquered cans intended for products containing anthocyanin pigments such as berry fruits and cherries. Colorimetric methods enable quantitative determinations to be made of the extent of corrosion due to lacquer film breakdown.

Chemical investigations of the liberation of labile sulphur from animal tissues during heat processing were continued. The aim of this work is to develop a standard test medium for determining the staining resistance of commercial sulphur-resisting can lacquers.

There is a demand for can lacquers of better performance for certain specialized products and developmental work is being conducted in close co-operation with lacquer manufacturers. Seven new types of acid-resisting lacquers and eight sulphur-resisting formulations were tested during the year. Several of these show promise but tests are incomplete.

(*e*) *Equipment.*—Extensive modifications were made to the pressure spin-cooker constructed last year. The improvement in quality obtained by agitating the product was demonstrated on a number of heat-sensitive foods. Further studies will relate to the effects of varying the rotation rate and headspace volume on the rate of heat penetration.

10. DEHYDRATED FOODS.

(Division of Food Preservation and Transport.)

(*a*) *Vegetables.*—The deterioration of dehydrated carrot coated with starch and starch fractions was studied. Amylopectin, alone or as whole starch, gave a slightly beneficial effect.

As "in-package" desiccants for reducing the moisture content of dehydrated vegetable and thus prolonging the storage life, crude samples of Australian bentonite clays showed a lower water vapour uptake than samples of processed American material. After activation treatments, however, the local clays were at least equal to American types.

The expansion of freshly compressed dehydrated vegetable is usually prevented by holding the blocks in a special press. Carrot and cabbage samples were compressed and packed immediately into No. 2½ cans and sealed. The cans acted as satisfactory holding presses, and after four months' storage in nitrogen the blocks could not be differentiated from control samples.

(*b*) *Fruit.*—Initial experiments dealing with the uptake of sulphur dioxide gas by cut fruits before dehydration were made. Information was obtained on the effects of the concentration of sulphur dioxide in the air, the variety of fruit, its maturity and size, and the time of exposure to gas. Data were also obtained on the depth of penetration of the gas, and on losses from freshly sulphured fruit in still air and in the initial stages of dehydration.

(*c*) *Meat.*—(i) *Dehydrated Mince.*—In previous years a comprehensive study was made of a number of factors likely to affect the initial quality of air dried mutton mince. From the results of these experiments it was possible to select a method of processing which would yield a mince of good initial quality. It was essential, however, to determine the shelf life of the product under different conditions in order to obtain a general estimate of its usefulness in the field.

A long-term storage experiment, which has just been completed, was designed to obtain a measure of the storage life of dried mince at a number of different storage temperatures with different methods of packaging. An illustration of the enhancing effect on shelf life of removing air from the packs is: at 30° C. (average for tropical conditions) an air pack has a shelf life of approximately six months, a block eighteen months, and a nitrogen pack 24 months.

Drying meat in forms other than mince often necessitates using only certain parts of the carcass, the remainder being dried as mince. Comparison of the storage lives of dried minces prepared from different parts of the carcass suggests that no one part yields a product comparable to that prepared from the whole carcass.

Methods for improving the naturally bland flavour of dehydrated mutton mince and also of extending its storage life by the addition of flavouring materials have been investigated. Storage studies involving additives are now in progress.

(ii) *Dehydrated Slices.*—Storage studies on compressed slices were recently completed; as with dried mince, nitrogen packing prolonged the shelf life. The storage life of slices was considerably less than that of dried mince.

11. FROZEN FRUITS AND VEGETABLES.

(Division of Food Preservation and Transport.)

Investigations on the freezing of fruits and vegetables are conducted jointly by the New South Wales Department of Agriculture and the Division of Food Preservation.

In the early stages of this work it was necessary to examine overseas techniques on a wide range of locally grown fruits and vegetables. These preliminary trials have led to more detailed projects dealing with particular problems. The absence for a major part of the year of one officer associated with this work brought about a temporary reduction in the programme.

(*a*) *Freestone Peaches.*—Fewer varieties were used in freezing trials during the year but the testing of material was extended to growing areas not previously studied.

Experiments on the effect of varying amounts of antioxidant on quality and storage life were continued. Some preliminary studies made in a previous year had failed to give conclusive results. Methods of determining ascorbic acid in frozen peach packs required special attention and a satisfactory technique for sampling defrosted material has now been developed.

(*b*) *Apricots.*—Detailed investigations on the use of antioxidants in the freezing of apricots have indicated that sulphur dioxide in small amounts will give satisfactory control of discoloration and will not impair the flavour of the finished product. Several different methods of incorporating sulphur dioxide in the pack were compared and showed no marked differences. Tasting tests did not reveal differences between the different levels of antioxidant used in these experiments. Much time was devoted to methods of determining sulphur dioxide and to the factors causing an apparent loss of this substance after freezing, storage, and defrosting.

(*c*) *Pineapples.*—The occurrence of an off-flavour in frozen pineapples has been investigated over the past few years. Fairly definite evidence was obtained that off-flavour development was influenced by the maturity of the fruit and to a lesser extent by the method of packing. The use of puréed material to simplify tasting and accentuate off-flavours did not appear to be promising.

(*d*) *Berry Fruits.*—In conjunction with the Tasmanian Department of Agriculture and the Organization's Tasmanian Regional Laboratory, work on the freezing of berry fruits has been continued. Preliminary tests on varieties, methods of packing, and storage at different temperatures have been carried out.

(*e*) *Peas.*—Experiments on the relationship between stage of maturity and acceptability of the frozen product were continued during the year. Previous results had suggested that graded peas in the range 10-14 per cent. alcohol-insoluble solids (A.I.S.) were highly acceptable, and an objective of 12-13 per cent. A.I.S. on the graded material was tentatively recommended. Work for the past year has in general confirmed these results, the optimum A.I.S. value probably being between 12 and 14 per cent.

(*f*) *Freezing Rates.*—Tests on the experimental air blast freezing unit were made, and after a number of modifications to the equipment satisfactory performance was achieved. This equipment will be used later in obtaining essential physical data on frozen foods.

12. Wine.

(Oenological Investigations, Waite Agricultural Research Institute.)

The investigations directed by the Committee on Oenological Research have been continued at the Waite Agricultural Research Institute.

The work is concerned with the investigation of problems of the wine industry, with a view to improving the quality of Australian wines. Present investigations comprise a study of yeasts used in the primary fermentation, and bacteriological changes occurring during maturation.

(*a*) *Wine Yeasts.*—The objects of the work is to investigate differences between wine yeasts in order to select those yeasts which are most suited to the requirements of the winemaker. The work has been extended to include the influence of mixtures of pairs of yeasts on the quantity of ethyl alcohol produced in the wine. The results obtained have been interesting and will assist the winemaker in making the most effective use of selected yeast starters. Various methods of yeast storage have also been investigated and recommendations have been made. Private firms have materially assisted in these investigations by making winery facilities available.

(*b*) *Malo-lactic Fermentation.*—Examination of a collection of samples of 1953 dry wines showed that a malo-lactic fermentation occurred in about half the wines examined. In many wines bacterial activity was suppressed by low pH values or by high doses of sulphur dioxide used at vintage. Since the malo-lactic fermentation is most beneficial when it occurs in wines with low pH values, present work is concerned with the effects of different factors on the acid tolerance of the bacteria.

13. Dairy Products.

(Dairy Research Section.)

(*a*) *General.*—The better use of the non-fat milk solids produced in Australia remains one of the major objectives of the Dairy Research Section. Work to this end during the year has been directed largely to seeking application of the technical information already obtained, particularly in the addition of milk solids to bread, but progress has to some extent been hampered by lack of suitable development organization within the dairy industry. The rapid headway which has been made in developing a new cheese-making method must also in the long run further the better use of the non-fat solids of milk. While the Section in its earlier history had largely to neglect fundamental studies, work initiated some years ago on the chemistry of oxidized flavour in milk has now given important results.

Recent expansion of the staff has utilized the additional space provided by the prefabricated building at Highett. The permanent laboratories on that site are being erected rapidly.

As in previous years some of the applied work of the Section has been closely linked with the activities of State Departments of Agriculture, as well as with many dairy product companies, and the co-operation of these organizations is gratefully acknowledged. Financial support for commercial-scale development of new cheese-making methods has been provided to the extent of £5,000 by the Australian Dairy Produce Board.

An officer attended the 13th International Dairy Congress at The Hague as an official Australian delegate.

(*b*) *The Utilization of Skim-milk Solids.*—One line of investigation aimed directly at the use of skim-milk solids as human food is the development of products which will replace eggs in cakes and confections. Irregularities in the behaviour of the product for sponge cakes were eliminated by neutralizing with acid after treatment with a calcium-sequestering agent and with alkali. A patent application for the process has been filed. The use of rather higher temperatures has permitted a shortening of the manufacture.

(*c*) *Oxidized Flavour in Milk.*—Bottled milk supplied in Australian cities frequently suffers from the flavour defect described as oxidized or cardboard. Investigation of the chemical compounds responsible for this flavour has called for microtechniques for the isolation and identification of 2, 4-dinitrophenylhydrazones. These have been successfully developed and it has been shown that the flavour is mainly due to aliphatic 2-enals in the 8-10 carbon atom range, and to 2, 4-dienals. About eight enals and at least four 2, 4-dienals have been isolated from the steam distillate from cardboard-flavoured skim milk.

(*d*) *Susceptibility of Butter Fat to Oxidation.*—In studies on variations in the inherent susceptibility of different butter fats to oxidation, fats prepared from the same milk under identical conditions have shown appreciable variations in rate of oxidation. Work on this project has been temporarily suspended.

(*e*) *Stability of Vitamin A in Skim-milk Powder.*—One of the chief nutritional weaknesses of skim-milk solids, particularly for infant feeding and for use in Asiatic countries, is the lack of vitamin A. Synthetic vitamin A is available and the problem is to find a method of incorporating it in dried skim milk which will render it stable during storage at high temperatures. Various lipids with and without stabilizers are being tested as vehicles for the vitamin.

(*f*) *Structure of Dairy Products.*—Investigations into openness, a common defect of the texture in Victorian butters, have been carried out in co-operation with the Victorian Department of Agriculture. The defect was found to be most common in butters from metal churns and with unwashed grain, and both temperature regulation in the churn room and careful control of all working conditions are necessary for its elimination. Variations in the chemical constants of the fats did not appear to be an important factor.

A procedure for the fluorescence microscopy of fat in milk and dairy products using phosphine (in aqueous solution except for milk powders, for which a glycerol solution was used) was developed and applied.

The fat-globule membrane lies at the interface of the fat and aqueous phases in dairy products and is the site of many of the most important chemical and physical changes which these products undergo. Elucidation of its chemical and physical structure has been undertaken as a major project, and much time has been devoted to a study of the literature.

(*g*) *Cheese Starter Studies.*—Phage-carrying and lysogeny phenomena in cheese starter organisms were further investigated; one artificially prepared lysogenic strain is operating successfully under commercial conditions. Studies on compatibility have been continued.

Further single-strain cultures suitable for commercial use have been isolated. The effect of various types of starters on the texture and flavour of Cheddar cheese has been investigated.

(*h*) *Cheese Manufacture.*—As part of a broad project for the further mechanization of the cheese-making process, a general review of the process itself was undertaken. In conjunction with the introduction by the United States Department of Agriculture of *Streptococcus durans* as a cheese starter, these investigations have already led to the development of a new method for the manufacture of Cheddar cheese. The total time for setting to hooping has been reduced from 4¾ hr., the best previous Australian practice (5-7 hr. elsewhere), to less than 3½ hr.

(*i*) *Viscosity of Cream.*—While many investigations have been made overseas on the viscosity of table creams, data on the viscosity of fresh, acid, and neutralized creams for butter-making is not available to the designers of pumps and other cream processing machinery. Observations on the viscosity of a wide variety of such creams have therefore been made.

(*j*) *Other Investigations.*—Studies have been made on the use of refractive index as a measure of the total solids content in skim milk concentrated for drying; on some technical aspects of malted and chocolate milk drinks; on methods for testing fat in milk, using surface active agents; on the effect of static charge on bulk density in dried milks; on the air content of butter; and on bacteriological defects in sweetened condensed milk.

14. Dried Vine Fruits.

(Commonwealth Research Station, Merbein.)

Drying rates for the latest commercial oils for the cold dipping of sultanas were compared in field trials, both early and late in the harvest period and for both fresh and used dips. Manufacturers had made some changes in their formulations, and this year no notable differences in drying rate were found between the various oils on the market.

Laboratory comparisons have been made of some details of cold dip preparation for sultanas. In one trial, degree of sulphation of the oil made little difference to the drying rate of fruit, but this result was complicated by an effect of sulphation on emulsion stability. In other trials cation and anion effects were examined. When potassium was used instead of sodium for neutralizing a sulphated oil before its incorporation in a dip, no notable difference was found in dip behaviour. Confirming earlier findings, the use of sodium instead of potassium in the dispersing medium for the oil added to the dip resulted in a darker colour of the dried sultanas. With sodium salts seven anions have been put in order of effectiveness in increasing rate of water loss, and their different behaviours in the presence of dipping oils have also been assessed. The physical state of the emulsion appears to be as important as the chemical ingredients in the dip, less stable emulsions increasing drying rates.

Investigations continued on the use of the hot sulphite dip for sultanas, which was used very widely in the mid-Murray area during the 1954 harvest. This area produced fruit of better average quality this year than ever before. Probably this was due partly to the good drying weather and partly to the widespread use of the sulphite dip. The bulk handling of fruit with a hot sulphite dip proved quite practicable and a start was made in establishing a relation between dipping time and dip temperature for the best result by this method. Tests over a full dipping day showed that no decomposition or selective removal of sulphite occurred.

No advantage was found in adding sodium sulphite to the hot caustic soda dip for gordos, except possibly in inhibiting later insect attack.

Experiments on rack dehydration at Woorinen, Victoria, were again conducted last autumn. Modifications made to the equipment included the use of a large combustion chamber and a larger main fan driven from a tractor, and the distribution of hot air in ducts running from the centre of the rack to each end. These changes proved useful, although further improvements can now be suggested.

15. Washing of Dried Vine Fruits.

(Central Experimental Workshops.)

Development of equipment for the washing of dried vine fruits is being undertaken in conjunction with the Australian Dried Fruits Association. The removal of dirt from the surface of the berries is a problem which has been confronting the industry for a long time. The difficulties arise from the fact that the fruit will deteriorate if left in contact with water for any appreciable time, yet adequate washing necessitates a complete wetting of the surface, together with sufficient abrasion to remove any dirt embedded in the folds of the skin.

In order to obtain data for the design of suitable equipment to perform this washing operation, a number of test rigs were built and tested to determine the factors influencing washing efficiency, damage to fruit, and efficiency of removal of surplus washing solution. It was also found necessary to develop a suitable method of measuring the cleanliness of fruit.

This work led to the construction of a prototype machine which comprises a washing machine, a rinser, and a continuous-flow centrifuge which removes most of the water left on the fruit during the washing operations. Since the centrifuge embodied certain novel features and appeared likely to have wider application, steps were taken to patent this machine.

The complete washing machine, rinser, and centrifuge equipment is being tested by the industry to determine its suitability for commercial exploitation. It has been shown to be satisfactory in removing dirt from fruit, but problems have arisen in connexion with the "packability" of the fruit after washing. These are thought to result from the presence of more than normal sugar on the surface of the berry, but the factors influencing "packability" are not clearly understood and call for further investigation.

XIV. FOREST PRODUCTS.

1. General.

In spite of the wide range of eucalypts and other species of timber available, Australia is not a heavily forested country. Full and proper exploitation of our timber resources is therefore essential, and this can only be achieved with the aid of fundamental data on the properties, potentialities, and correct methods of treatment of our timbers.

The Organization's Division of Forest Products, with its laboratory in Melbourne, was formed to carry out investigations into Australian forest products and to give direct assistance to all concerned in the utilization of forest resources. Its work is directed toward the more effective use of these resources by reducing waste in forest, mill, and factory; by reducing losses from decay and insect attack; and by improving the quality of timber produced in the growing forest by study of the relationship between silvicultural treatment and timber products. The work of the Division is reported in this Chapter. Some work on timber pests is undertaken by the Division of Entomology (*see* Chapter IX.).

Division of Forest Products.—The timber and allied industries were once again operating at a high level during the year. The recent recession has created a more cautious attitude towards imports, a desire to use available timbers to the utmost extent, and a recognition of the need for standardization, improvement of practices, &c. Under these conditions the demand for assistance in the applied aspects was comparable with last year, with some 8,000 inquiries and some 1,600 visitors.

In basic investigations, emphasis was again placed on the structure of the wood fibre, the chemistry of wood, and pulp and paper work. On the applied side, fence post investigations were given preference. To maintain these activities in addition to the heavy load of inquiries without increasing staff, has required severe pruning of programmes in some fields.

The Division suffered a serious loss in the death of Mr. A. J. Thomas. He was an officer of the Division in pre-war days, was seconded to the Ministry of Munitions as Assistant Controller of Timber, and returned to the Division after a period in industry.

Of recent years the wooden case industry has lost part of its market to fibre and metal containers, and to arrest this trend improved design and standardization of packages appeared necessary. The Division was asked to re-enter the field of case design, and it agreed to do this providing a substantial contribution towards the cost was made by industry. Following the provision of approximately £1,000 per annum for this purpose, the Wooden Case Research Committee, consisting of representatives of the contributors and officers of the Division, was set up and investigations were commenced.

The Division was represented at the Eighth Pacific Science Congress in Manila. The officer in charge of wood and fibre structure investigations made a short visit at the end of the year to attend conferences on wood anatomy and cellulose chemistry in Europe.

Arrangements were made to locate some of the Division's timber mechanics work in the School of Engineering at the University of Western Australia. One Research Officer, one Technical Officer, and an Assistant were transferred to Western Australia, and investigations into the properties of wooden structural members were commenced.

The Forest Products Research Conference held in April, 1954, in Melbourne, was well attended by representatives from the State forest services, the New Guinea Department of Forests, and the Forestry and Timber Bureau, as well as a number of other Commonwealth organizations.

The Pulp and Paper Co-operative Research Conference was held in October, 1953, and was well attended by the representatives from the contributing companies. All companies have now agreed to double their contributions for this co-operative work. The Eighth Australian Pulp and Paper Industry Technical Association Conference was held in Hobart and a strong contribution was made by officers of the Division.

The Division joined the Division of Wood Technology of the New South Wales Forestry Commission in providing an exhibit at the Architects' Convention in Sydney in May, 1954. An exhibit was also provided for the Australian Nature Show at Prahran Town Hall (Melbourne) in October, 1953.

Courses of study at the Division were given to fifteen students of the Australian Forestry School, Canberra, and to six from the Victorian Forestry School, Creswick. Lectures to students in architecture and forestry at Melbourne University were continued. The correspondence course in kiln operation was continued, eighteen students completing one or other of the two courses available. Twenty-six students were enrolled. A number of lectures and broadcasts were given throughout the year on various subjects relating to the work of the Division.

The help and co-operation of the paper companies the wooden case industry, the Commonwealth Forestry and Timber Bureau, the State forest services, the New Guinea Department of Forests, and other branches of the timber and allied industries are gratefully acknowledged.

2. Wood and Fibre Structure.

(Division of Forest Products.)

(*a*) *Anatomical Investigations.*—(i) *Wood.*—The study of the anatomy of timbers occurring in the south-west Pacific area has been continued, and wood of the Burseraceae, Cunoniaceae, Podocarpaceae, and Flacourtiaceae have been examined. The comparison of the anatomy of the New Guinea species of *Nothofagus* with that of the species occurring in other part of the world has now been completed.

(ii) *Bark.*—In the study of bark anatomy, 460 specimens of 41 species of the genus *Eucalyptus* have been collected and examined during the year. It ha been possible to make assessments of hybrids on bark features, and such assessments have coincided with those made on morphological characters.

(*b*) *Identifications and Identification Methods.*—Over 450 timber specimens from trade sources, government departments, and individuals have been identified during the year. In addition some 800 specimens o sleeper timbers and 770 specimens of crossarm timber were identified in connexion with surveys. Identifications of several hundred New Guinea timbers have been made to assist in the botanical determinations o material collected by the New Guinea Department o Forests, and also by the Organization's Land Research and Regional Survey Section. Over 160 timber specimens from Dutch New Guinea were identified for the forest authorities there. Fifteen sets of card-sorting keys based on macroscopic features have been distributed, and information concerning card-sorting key forwarded to forest authorities in the Philippines Sarawak, and Indonesia.

(*c*) *Tension Wood.*—Three different types of tension wood fibres have been observed. In each a typica gelatinous layer is present but the number of other layers of the secondary wall varies, as does their degree of lignification. Details of the fine structure of the gelatinous layer have been revealed by the electron microscope. Field experiments have been carried out on stems and twigs with the object of studying the development of tension wood. It has been concluded from experiments to date, that the formation of tension wood is the response of the stem or part thereof to stimuli necessary to achieve or maintain inherent characteristics of form. It has also been demonstrated that changes paralleling those in the wood take place in the bark. The bark fibres formed on the tension wood side have a structure comparable with that of tension wood fibres and different from that of the bark fibres on the opposite side of the stem. Various properties of tension wood such as woolliness on sawing high longitudinal shrinkage, and irrecoverable collapse on drying have been interpreted on the basis of the knowledge gained of the fine structure of the various layers of the cell wall.

(*d*) *Cell Wall and Fibre Studies.*—(i) *The Intermicellar System of Cellulose Fibres.*—The capillary system of wood fibres is of importance in the penetration of preservatives and reagents into wood. The magnitude of capillary spaces has been investigated in fibres from spruce, various eucalypts, and flax, using the method of gold deposition and determining the apparent crystal size of the gold particles from the line-broadening in the X-ray diffraction diagram. The earlier objection to the use of this method, namely, that crystallization of the gold in the walls of the fibres artificially increases the size of the capillaries, is justified, but the method does give some indication of the relative size of the capillaries because the particle size of gold is greater in the various specimens after they have been delignified. Examination of gold-impregnated material by means of the electron microscope has resulted in a visual demonstration of the intermicellar system. The breadth of the capillaries in flax ranges between 80 and 130 Å, a value in reasonable agreement with the 120 Å deduced from X-ray results.

(ii) *The Mechanism of Surface Growth in Plant Cells.*—Evidence has been obtained that surface growth in fibres and tracheids during differentiation proceeds by localized tip growth of the cell and, in the body of the cell, by the so-called "mosaic" growth in which it is visualized that at a number of points in the primary wall the microfibrillar network of cellulose is pushed aside by localized cytoplasmic synthesis. This process, acting under cell turgor, enlarges the surface, and the enlarged area is subsequently interwoven with new microfibrils of cellulose. It has been suggested that the thin areas participating in mosaic growth are in fact areas in which the cell walls are penetrated by plasmodesmata. In terms of this concept the co-ordinated growth existing between the cells can be understood, and much of the minute anatomy of cell walls may be regarded as manifestations of localized growth occurring in the regions of what are initially plasmodesmata.

(*e*) *Structure in Relation to Properties.*—Spiral grain, compression wood, and large fibril angle are anatomical features which are associated with the warping, twisting, and general misbehaviour of boards cut from young stems or the centre portion of certain plantation-grown conifers. Specimens of *Pinus taeda, P. caribaea,* and *P. ponderosa,* all species in which trouble has been reported, have been and are being examined. High longitudinal shrinkage values have been obtained for the wood from successive growth rings from the pith in *P. taeda* and *P. ponderosa,* and this seems to be associated with large fibrillar angles, which, instead of decreasing with age as expected, have remained high over some fifteen growth rings from the pith. However, it is considered that factors other than large fibrillar angle are involved and these are being investigated.

(*f*) *Bark and Wood Extractives.*—The leucoanthocyanins have been estimated in several tannin extracts by converting to anthocyanidins and determining these spectrophotometrically. The method still requires further work before absolute values can be obtained, but a correlation has been found between the amounts of leucoanthocyanins present and the tendency for the extract to impart a red colour to the leather. From other considerations it is probable that leucoanthocyanins are responsible for this colour, which renders many eucalypt tannins inferior as tanning agents. The reagent used in the estimation (propanol-hydrochloric acid) has proved valuable in converting other leucoanthocyanins to anthocyanidins; this hitherto could not be done efficiently. Attempts are being made to isolate these labile materials from blackwood and mallet. Extracts from barks of certain eucalypt species have been examined chromatographically to determine whether this technique can assist in the identification of hybrids.

3. Wood Chemistry.

(Division of Forest Products.)

(*a*) *Lignin and Related Compounds.*—Pending completion of a Craig machine a small quantity of lignin has been resolved by the counter-current method by hand. Chromatography on borate paper, which heightens the fluorescence of lignin fractions, gave a single spot with a faint halo, probably indicating some remaining impurity. Oxidations of some pulps containing only small percentages of lignin have been carried out and the oxidation products shown to be substantially the same as those from native lignin, i.e., mainly vanillin and syringaldehyde. A quantitative method for the determination of these products has been evolved. The behaviour of several different sugars during Klason treatment has been studied; only fructose produced a significant amount of a substance indistinguishable from acid-soluble lignin.

(*b*) *Wood Carbohydrates.*—The two fractions of the water-soluble carbohydrate material prepared from methanol-cooked wood have been examined by acid hydrolysis and separation of the resulting sugars on a cellulose column. Fraction 2 (precipitated by 90 per cent. ethanol) gave glucoronolactone, xylose, and galactose. Crystalline derivatives have been obtained from the xylose and galactose, and their identity confirmed by X-ray powder diffraction diagrams. Fraction 1 (precipitated by 60 per cent. ethanol) appears to differ chemically from fraction 2. Investigation of the alkaline extraction of wood (*Eucalyptus regnans*) indicated that the maximum yield of a lignin-free pulp obtainable by alkali cooking would be 55 per cent. Treatment of holocellulose with 0.1 per cent. sodium hydroxide left a residue equal to 66 per cent. of the original wood, but treatment with 5 per cent. alkali left a 53 per cent. residue. Evaluation of the paper-making quality of these residues showed that the one containing the large amount of non-cellulosic polysaccharide gave better bonding in the unbeaten state and developed bonding more rapidly during beating.

(*c*) *The Mechanism of Delignification.*—A more detailed study of the influence of chip shape on the delignification of *E. regnans* wood by sodium hydroxide and by sodium sulphide has been completed. The results show that the rate of delignification is greater in the longitudinal direction than in the radial, and least in the tangential direction. This effect is much more definite with sulphide than with hydroxide cooking. Pentosan removal appears to be independent of the shape of the chip.

(*d*) *Pulping of New Guinea Woods.*—Pulps were produced from *Araucaria* spp. in yields of 54-59 per cent. by the sulphite process, but their strength properties, particularly tearing resistance, were much lower than for the corresponding sulphate pulps. The sulphite pulps had low pentosan contents and this, together with the high yields, indicated that they might have possibilities for conversion to a dissolving grade pulp.

Representative samples of *Eucalyptus deglupta* and *Rhizophora apiculata* pulped readily, using the sulphate process, to give pulp yields of 50 per cent. The former gave a pulp only slightly inferior in strength properties to commercial eucalypt kraft pulps. The latter compared favourably in tearing strength, but was lower in all other strength properties. Mixtures of woods of the mangrove association have been pulped successfully by the sulphate process. Preliminary investigations have indicated that some of the light-coloured, low density woods may be used for the production of groundwood. Of these *Camptostemon schultzii* and *Excoecaria* spp. are the most promising.

(*e*) *Beater Studies.*—Comparisons have been made between the beating effect of the standard Lampen mill and that of the same mill when fitted with a ball of standard weight but 2.5 mm. less than standard diameter. The non-standard ball beat at about half the rate of the normal ball. The precision of the Aylesford beater has been increased by improving the setting and alignment of the beating surfaces. Investigations have involved beating at certain fixed clearances between the beater surfaces, using different cone speeds. This gave a pulp which, at the highest cone speed and the lowest clearance, showed strength developments only slightly less than those obtained with the Lampen mill. There was little evidence of fibrillation of these pulps when observed at high magnifications.

The presence of direct dyes of the benzidine class has been shown to influence the beating characteristics of pulp. Eucalypt pulp beaten in distilled water containing small but increasing amounts of congo red showed increases in strength properties, the amount being proportional to the logarithm of the dye concentration. This effect was shown to be due to the dye itself and not to its reactive groups.

(*f*) *Folding Endurance.*—The performance of the Köhler-Molin fold tester has been investigated for a range of eucalypt papers. This instrument incorporates many improvements suggested by earlier investigations on the M.I.T. fold tester. A detailed study has been made of structural factors influencing the folding endurance of paper, and of the relation between fold and rheological properties. The use of fibre fractionation, fibre blending, and other procedures pointed to the strong influence which fines exert on the folding endurance, at constant basis weight. Part of this effect may operate through differences in density.

(*g*) *Rheological Properties of Paper.*—The rheometer which was built in the Division has been used to record stress-strain, creep, and relaxation curves on paper strips in tension. The development of tension within the drying sheet at constant length, and the change in length at zero stress, have been followed as functions of time and moisture content for eucalypt kraft papers beaten to different degrees. The rheometer was also used to impose directed stresses on wet strips so that the mechanical conditioning imparted to machine-made paper by the tension on the draws could be simulated under controlled conditions, and its effect on the paper properties assessed. The effect of drying under isotropic restrain has also been examined.

(*h*) *The Mechanism of Beating.*—An examination was made of the effect of colloidal material liberated during beating on the properties of the paper. The results suggested that the colloids which can be removed readily from the fibre do not play a leading part in the development of strength. Experiments on the contribution of fine fibrous material to paper strength led to the formulation of the hypothesis that the post-yield portion of the stress-strain curve depends primarily on the inter-fibre characteristics of the paper and that the initial portion reflects the nature of the fibre network itself. Very highly beaten pulps yield papers with properties rather similar to papers made from fine pulp fractions.

(*i*) *Adhesion within Paper Sheets.*—Chemical modification of cellulose fibres has been used to reduce their hydrogen-bonding capacity and to study the effect on the resultant properties of the paper.

(*j*) *Viscosity Studies on Cellulose.*—The intrinsic viscosities in cupriethylenediamine of beaten and unbeaten α-cellulose, partially acetylated α-cellulose, and eucalypt and pine kraft pulp have been determined. Neither beating nor light acetylation materially affected the intrinsic viscosity of the α-cellulose, which was *c.* 2.8, nor the slope of the reduced viscosity-concentration curve.

(*k*) *Groundwood Investigations.*—In collaboration with the research staff of a newsprint mill, studies have been commenced on the rheological properties of handsheets made from typical pulps of different qualities. It was found that for a particular wood specimen, tenacity, extensibility, Young's modulus, and rupture energy all increased as the freeness was reduced by varying the grinding procedure. Rheological tests were also made on the woods from which the pulps were derived, with the aim of developing an index of groundwood quality.

4. Timber Physics.

(Division of Forest Products.)

(*a*) *Sorption Studies.*—(i) *Sorption Phenomena*—In the study of the effect of temperature on the sorption of water by wood *in vacuo* the humidity is now being satisfactorily controlled by sulphuric acid solutions. Measurements already made indicate that the width of the hysteresis loop decreases with increase in temperature. Additional apparatus has been constructed to extend the tests down to —40° C.

To study sorption at relative humidities above 98 per cent. a pressure membrane apparatus has been designed and a prototype constructed, based on that used for the study of soil moisture equilibria.

The precision calorimeter for studying the heat of sorption of water by wood has been further developed by incorporating a precision A.C. bridge to measure the temperature rise of the calorimeter vessel.

Exploratory tests were carried out on the removal of moisture from wood by extraction with a diacetone alcohol-petroleum ether mixture. It was found that a reported reduction in shrinkage was due to retention of some diacetone alcohol by the wood, and subsequent evaporation was accompanied by shrinkage to the normal extent. The method is considered to have no practical application in the seasoning of wood.

In estimating shrinkage intersection points, tests have shown that the value calculated from shrinkage between 12 and 5 per cent. moisture content is not significantly different from the true value obtained by extrapolation of the straight line portion of the shrinkage-moisture content curve. Differences have, however, been observed between the true shrinkage intersection points and the value calculated from basic density and volumetric shrinkage to 12 per cent. moisture content.

The equilibrium moisture content of Pacific island timbers with unusualy low intersection points is being compared with that of normal species.

(ii) *Shrinkage and Density Measurements.*—Shrinkage and density tests have been completed on a group of north Queensland species, on seventeen *Pinus radiata* trees of various ages, and on 101 trees of major Australian species on which further data were required. The shrinkage and density of the wood of certain eucalypt hybrids and parents have been further examined; the properties of the hybrid are intermediate between those of the parents.

The shrinkage-moisture content relation for a wide range of hardboards has been further investigated, tests being carried out over repeated cycles of conditioning.

(iii) *Creep and Related Phenomena.*—A quantitative comparison of creep at constant stress with stress relaxation at constant deformation showed that to a first approximation wood behaves as a linear viscoelastic body. The response to any loading condition can therefore be predicted approximately if a single relationship, e.g., the creep function, is known. Deviations from linearity appear to be due mainly to irrecoverable deformation increasing more than proportionally with stress. This was corroborated by the results of shear and tension tests. Creep at high stresses was observed to occur, not continuously, but in rapid discrete increments. Macroscopic and microscopic local compression failures were found to require time to develop, increasing with time even when the overall deformation was constant.

Further tests on air-dry mountain ash beams under continuous loading and during recovery after unloading have confirmed previous findings as regards the form of the creep function. Seventy-five per cent. of beams loaded to three times the design stress have failed after periods varying from two to 18 months and 50 per cent. of beams loaded to twice the design stress have failed after two and a half to three years. The Young's modulus of air-dry mountain ash in bending was found to increase somewhat with time under load. Additional observations on green and dry mountain ash under either continuous tensile or compressive stresses have confirmed that creep continues for at least three years in tension and one and a half years in compression. The proportional increases in strain are similar in both tension and compression for periods of at least one and a half years; the increases for green material are slightly higher than those for dry. No creep has been observed in dry compression specimens held under stresses of less than 10 per cent. of the short-time strength for one and a half years. In tension and bending, creep was observed at these low stresses.

(iv) *Electrical Properties.* — The dielectric constant and power factor of samples of white cheesewood from five trees impregnated with boric acid and borax, each at seven concentrations, have been measured at five frequencies and three moisture contents. No significant change in these properties was detected as a result of impregnation with boric acid. The results for borax impregnation are being analysed.

Moisture meter correction figures have been determined for a further eleven species.

(v) *Strain Gauges.*—Limited tests have been made on printed foil gauges, glued with various "epoxy" resins, to determine their suitability for use on wood.

A 5-in. single-strand wire gauge has been developed for tests on beams to check the movement of the neutral axis during continuous loading.

A new type of bridge for use with electrical resistance strain gauges has been developed. It is designed especially for creep tests and incorporates inductive ratio arms.

5. TIMBER MECHANICS.

(Division of Forest Products.)

(*a*) *Studies of Properties and Testing Methods.*—The relationship between impact strength and moisture content is more complex than for static strength properties, and attempts to establish an empirical formula have not been successful.

Data obtained from investigations of the effect of size specimens in the determination of Izod value have been analysed. Comparative studies of the dropping ball technique and the Janka hardness method indicate that they give values which are closely correlated with each other and also with the density of the wood.

A preliminary investigation has been made of the effect of different rates of loading in the testing of fibreboards. This indicates that the effect of rate of loading is similar to that for timber testing. It has shown also that in bending tests the span, the shape of the support, and the friction developed all have a significant effect on the modulus of rupture.

(*b*) *Species Testing.*—Material for mechanical testing came from South Australia, Victoria, New South Wales, and Queensland, and species tested included brush box, tallowwood, turpentine, spotted gum, rose gum, and various stringybarks, boxes, ironbarks, and peppermints. A full range of tests was completed on green material from 80 logs and on dry material from approximately 170 logs. In addition minor tests were conducted on green material from 10 logs and on dry material from 17 logs. Tabulations are being made of the mechanical properties of approximately 100 Australian species.

(*c*) *Silvicultural Tests.*—The investigations of the relationship between silvicultural treatment and mechanical properties of pines have been continued with tests in compression, bending, and toughness on specimens of *P. taeda, P. carribaea,* and *P. radiata.* Density and percentage late wood determinations have also been made. The data from a very large number of tests are being analysed, but already it is clear that density alone accounts for more than 80 per cent. of the variation in strength of wood, and that density and age together account for nearly 90 per cent. of the variation. Rate of growth appears to have no significant effect on strength other than indirectly from its high correlation with both density and age.

From determinations of mechanical properties, it appears that the hybrids are intermediate between the parent species in strength, and their properties vary according to the degree of hybridization.

A new model microtester has been designed and placed in service. It is being used to determine whether the tensile strength of early wood and late wood of *P. radiata* varies with distance from pith.

(*d*) *Timber Construction.*—Long-time loading tests on simple tension joints with split-ring connectors and shear plates have continued for nine years. Analysis of results has now commenced.

Testing of model columns under constant long-time loading has continued. Altogether 218 columns have been set up, 107 of mountain ash, 67 of yellow stringybark, and 44 of Douglas fir. Three slenderness ratios and three degrees of eccentricity are represented. All columns were erected green, but 91 have been allowed to dry out. To date, failure has occurred in 102 of the 125 columns loaded to 70 per cent. of their estimated short-time failure load. In the 60 per cent. loading group, 39 have failed out of 68 set up, and in the 50 per cent. loading group, twelve have failed out of 25 set up. There is some indication that under the same percentage of the short-time failing loads, the more slender columns are able to survive for longer periods than the short columns, but this will require confirmation. No significance of eccentricity of loading on column life is apparent at this stage of the investigation, but generally it appears that columns drying out fail more rapidly than matched columns kept green.

Investigations are being made of the effect of grain slope, gum veins, gum pockets, and pin-holes on the strength of jarrah scantling material. To simplify interpretation of results and to reduce the number of tests required to a minimum, specimens are being selected with the particular defects within preselected zones. The first scantling size being studied is 4 by 2 inches. Matched clear specimens are being tested in bending and compression.

A study is being made of the holding power of case nails in radiata pine, mountain ash, and karri. Variables include nail type and gauge and timber moisture content at driving and withdrawal. Similar studies are being made with building nails driven into karri and messmate stringybark, and include the strength of structural nailed joints using single nails in single and double shear, withdrawal tests, and the influences of rusting. Radiography is being used to study nail and timber reactions under load.

(*e*) *Growth Stresses in Trees.*—Further investigations have been made on factors which might be responsible for the development of splits during the heating of veneer logs. Species tested include radiata pine, alpine ash, and Douglas fir. An analysis of results indicates that for both alpine ash and radiata pine there is a highly significant decrease in strength perpendicular to the grain with increasing temperatures (110 to 210° F.) for all durations of pre-heating (4 min. to 72 hr.). For the lower part of the temperature range there is no significant effect of duration of pre-heating on strength, but in the upper part of the temperature range the decrease of strength with increasing time is highly significant.

6. TIMBER PRESERVATION.

(Division of Forest Products.)

(*a*) *General.*—There has been marked interest in the design and operation of wood preservation plants and in the economics of commercial treatment of sleepers, poles, crossarms, and other outdoor timbers.

(*b*) *Field Tests.*—The service tests of rail and tram sleepers, poles, fence posts, &c., which have been installed periodically since 1930 are of particular importance at present in demonstrating the benefits of treatment and in selecting preservatives and the best methods for their application.

During the year an inspection was made of radiata pine tram sleepers treated with creosote oil and installed at Ballarat in 1936. The treated sleepers are performing better than durable eucalypts in comparative tests. Treated New Guinea mangrove rail sleepers recently installed in the Melbourne metropolitan system are so far behaving favourably.

Installation of eucalypts sleepers treated with various preservatives in the Division's experimental high-pressure plant was commenced during the year in co-operation with the Victorian Railways. This test will include 3,000 sleepers and installation at the first of three sites has now been completed. Tests of treated sleepers will also be made in other States.

(*c*) *Causes of Failure of Rail Sleepers in Tasmania.*—In a survey of rail sleepers made in co-operation with officers of the Tasmanian Railways and the Forestry Commission of Tasmania, sleepers were examined in 42 different localities and the causes of failure determined for the different timber species used. Mechanical deterioration at the rail seat, combined with decay, were the principal causes of failure. Pressure treatment with a preservative oil could greatly increase service life and, as the life of untreated sleepers is at present only about eleven years, treatment is considered to be economic.

(*d*) *Preservative Treatment of Poles and Crossarms.*—Field tests of preservative-treated poles, and the results of the Division's recent survey of the causes of failure of crossarms, have been discussed with the Postmaster-General's Department and other pole-using authorities. As a result several treatment plants are now projected and officers of the Division are giving technical assistance in their design.

(*e*) *Development of Preservative Treatments for Fence Posts.*—During the year an intensive investigation has been made of treatment methods and equipment suitable for use by farmers for the preservation of round fence posts. The four methods recommended have given preservative absorptions proved adequate in service tests extending over the last twenty years. Simple treating equipment has been designed and a portable unit assembled in a trailer for demonstration at country centres.

A survey of fencing practices throughout Australia has also been conducted to assess the particular problems which exist in different States.

(*f*) *Properties of Wood Preservatives.*—Comparative tests with sapwood blocks of mountain ash and radiata pine have shown that timber species exerts a considerable effect on the rate of leaching and the degree of permanence of more important water-borne preservatives. With some preservatives there is differential retention of the component salts even in full cell pressure treatments. Tests are now in progress to determine the effect of the pH of the leach water.

Some of the leached blocks have been used to determine residual decay resistance by the soil-jar method. Preservatives most effective in preventing decay in small blocks (1 cu. in.) after 128 days' continuous leaching in distilled water were those based on arsenates or arsenites of zinc, copper, or nickel.

(*g*) *Timber Mycology.*—The main lines of work included: continued laboratory tests to determine the relative resistance to decay of the principal Australian timbers, similar tests to determine the relative protection, after weathering, afforded by eleven types of copper naphthenate and two types of naphthenic acid as compared with creosote oil and pentachlorophenol; identification of wood-destroying fungi from their cultural characteristics; laboratory production of fruiting bodies of basidiomycete fungi; effects of degree of aeration on the rate of decay in the soil-jar technique.

The tests with metallic naphthenates indicated that copper naphthenate prepared from acids of low acid number (below 200) is relatively unsatisfactory, but failed to show any marked advantage in using acids of very high acid number. Results also indicated that naphthenic acids should have considerable value as wood preservatives.

(*h*) *Termite Resistant Plywood.*—An investigation has been made of treatments to increase the termite resistance of plywood intended for use as flooring. Momentary dip treatments of $^1/_{10}$ in. green veneer of two eucalypt species were made using six different water-borne preservatives. Treated veneer was bonded into ½ in. plywood and speciments were supplied for laboratory termite resistance tests by the Division of Entomology. Two preservatives, sodium pentaborate and a zinc chloride-arsenic pentoxide mixture, when used in approximately 7 per cent. solution gave complete protection against *Coptotermes acinaciformis.* Precautions necessary in bonding were also studied.

(*i*) *Timber Borers.*—Tests are in progress to determine the minimum concentration of several preservatives required to prevent attack by the *Lyctus* beetle in seasoned sapwood of three susceptible timbers. Preservatives include "Tanalith", "Bolidens" normal salt, boric acid, arsenic pentoxide, and zinc chloride. Co-operative tests with the New Zealand Department of Scientific and Industrial Research have also been commenced to determine the degree of susceptibility of radiata pine to *Anobium punctatum.*

(*j*) *Miscellaneous.*—Various fungicides have been tested for effectiveness in rotproofing of paper and satisfactory results obtained with phenyl mercuric acetate, copper pentachlorophenate, and mercuric naphthenate. Other miscellanous investigations include tests on the decay resistance of cork and on the tolerance of various wood-destroying fungi to arsenic.

7. TIMBER SEASONING.

(Division of Forest Products.)

(*a*) *General.*—Industry continued to draw on seasoning research and technical facilities to a most marked degree. A trend towards installing driers as a means of improving plant efficiency continues.

(*b*) *Drying Studies.*—Studies were commenced on the influence of physical conditions on vapour movement in hardwoods. Work on the value of platen drying for veneers of the difficult "ash" eucalypt species was completed. Early impressions of the superiority of kiln and roller drying were confirmed. Studies were made of the effect of seasoning conditions on the rate and quality of drying of jarrah blocks for carbonizing. Consideration was given to the quantitative evaluation of drying degrade in sawn timber. Work to determine the moisture content of railway sleepers in service was continued, and earlier impressions that the core moisture content rarely if ever falls below "fibre saturation point" in the Melbourne area were confirmed. A further assessment was made of the influence of high temperature on the equilibrium moisture content (E.M.C.) of wood, particularly when drying in superheated steam and superheated steam-air mixes. A new E.M.C. control chart was prepared. Field studies determined the application of high dry bulb and low wet bulb temperatures, and rapid drying at high air velocities, as optimum kiln conditions for 1/16 in. thick karri veneers. Kiln schedule studies of mangroves, red stringybark, and a mahogany grown in Fiji were completed, and work on brown barrel of Victorian and New South Wales origin was continued. Limited studies on yertchuk, maiden's gum, southern mahogany, and grey box were commenced.

(*c*) *Kiln Design and Equipment.*—A new design of veneer kiln permits tray racking to be superseded by faster and more economic finger racking. In a commercial prototype, drying times of 65 minutes and 45 minutes are being obtained from 1/16 in. thick veneer of karri and ramin. Drying degrade has been greatly reduced. The major design feature is a double diffuser screen in each of the plenum chambers to permit high air velocities at a static head not greater than 0.6 in. water gauge.

The design of pre-driers was further developed, particularly with respect to heating and instrumentation. Performance tests were made on a unit with a charge capacity in excess of 200,000 super. feet, which is now operating successfully in Tasmania. Three additional units designed by the Division are almost complete.

Ninety-one visits were made to seasoning plants in all States to advise industry on the recognition and recovery of merchantable material, 8,000,000 super. feet of badly deteriorated timber, the modernizing of obsolescent kilns, the reduction of warp in timber and shrinkage in flooring, the improvement of plant efficiency, the suitability of handling equipment, kiln operation, kiln boiler performance, veneer drying, and moisture content control; and in one instance, to take charge of plant production temporarily to avoid a shut-down. Designs for kilns for sawn timber, core stock, veneer, and plywood were prepared for twenty firms in Australia and New Zealand; approximately 300 drawings were issued. Many discussions were held to clarify kiln construction methods, to assess the economics of operation, and to advise on superheated steam drying. Performance tests were made on a "packaged" kiln of European origin and new to Australia. Designs for McCashney burners were prepared for 38 firms; a modified design for burning green radiata pine sawdust of large particle size was developed and proved successful. Electronic equipment, designed to indicate automatically when drying veneer reached a predetermined moisture content, was developed and testing commenced. An attempt is being made to correlate temperature drop across the sheets with moisture content.

(*d*) *Collapse.*—Studies were commenced to find a quick field means for identifying collapse-susceptible timber in log form. Experimental work was commenced to examine the influence of temperature, vapour pressure, total pressure, drying rate, and a number of special pre-treatments on the intensity of collapse and recovery.

(*e*) *Seasoning Corresponding Committee.*—A Timber Seasoning Corresponding Sub-Committee, with the Division as convenor, was established within the framework of the British Commonwealth Forestry Conference Standing Committee on Forest Products.

(*f*) *Miscellaneous.*—The sufficiency of components of air-portable photographic huts was examined on behalf of the Royal Australian Air Force. Information on Australian seasoning practice was prepared for forestry authorities in Spain, Brazil, Chile, and Argentina, and for a supplier of Australian timber to the United States Army in Asia. The nature of "burning" in bagasse-resin combinations pressed at high temperatures for hardboard manufacture was studied. Preliminary studies were made of methods for preventing deterioration of timber in log dumps. A limited study of the accuracy of a high-range resistance type moisture meter was commenced. Studies were made of methods to prevent jamming of wooden components in cash registers used under "wet" conditions. The value of commercially reconditioned karri was examined. Studies were made of the drying of plaster board, the drying of case shooks, the conditioning of paper food containers, the influence of freezing on shrinkage of wood, the drying of shavings, and the drying of ragwort.

8. VENEER AND GLUING.

(Division of Forest Products.)

(*a*) *General.*—A restricted programme of work in the veneer and gluing field was undertaken with a reduced staff. The officer in charge of this work spent most of his time on wooden case research investigations.

(*b*) *Veneer Cutting and Utilization.*—Veneers were cut fom plantation grown logs of several coniferous woods in connexion with studies on the effect of knots on peeling knives, on distortion of the veneers during drying, and on the buckling of plywood made from them. Faces of knotty pine and centre veneers of the more rigid eucalypts minimized the tendency for the knotty veneers to buckle the plywood.

Logs of hekakoro (*Gluta* sp.), a New Guinea timber which has a high silica content, were peeled, dried, and glued into plywood.

(*c*) *Miscellaneous Activities.* — The Division co-operated with other Divisions, Commonwealth and State Government Departments, and industry by giving advice or assistance on topics including equipment for plywood plants, cutting techniques for peeled and sliced veneer, plywood corestock and furniture manufacture, glues for various purposes, development of a convenient hand-operated glue spreader, laminated railway sleepers, diving boards, and adhesives for end-grain floor blocks.

(*d*) *Wooden Case Research Activities.*—A general survey was made, commencing in the forests and sawmills and finishing in packing houses, railways, and wharves. Recommendations made have led to improvements in seasoning practices, the prevention of sap stain, improved selection of shooks, and the wider use of cement-coated or processed nails. Special attention has been given to cases for export of fresh fruits, dried fruits, and other commodities. A design and specifications for a lightweight nailed case has been approved by the Interservices Committee on Packaging for the transport of clothing for the armed services. Adoption of this specification has resulted in a direct saving of about one-third of the cost of the wooden container previously employed, with further advantages accruing from the reduced weight and volume. Some means of co-ordinating the production of short lengths of timber in saw-mills with the requirement of the case-maker are being sought.

9. TIMBER UTILIZATION.

(Division of Forest Products.)

(*a*) *Timber Uses.*—Information was supplied on timber for some 100 uses, and data were given on the properties of some 80 timbers.

(*b*) *Manufacturing Processes.* — In response to requests for assistance in planning new or improving existing plants, lay-outs were prepared for six saw-mills, two planing mills, one joinery works, one firewood yard, and two timber yards. Advice was given on production techniques for small pines, and on general saw-milling practices. Recommendations were made of methods for converting under-story species found in the eucalypt forest of a paper company. Advice was given regarding the design or operation of some 40 different classes of milling and finishing equipment. Other services were rendered in connexion with the finishing of flooring, furniture, bench tops, and turnery; the bleaching of wood; the construction of log cabins and portable huts; the remedy for squeaking floors, and the manufacture of wood-wind instruments, wood-wool, wood flour, and wood-cement boards.

(*c*) *Waste Utilization.*—Information was made available on briquetting and on uses for saw-dust generally. Attention of saw-millers and factory engineers was drawn to the value of saw-dust for steam generation. A study was made of the volume of saw-mill offcuts suitable for chipping at a Victorian saw-milling centre and interest aroused in its value for pulping.

Following the hydrolysis of one ton of sawdust for field trial as a soil improver, work continued in the laboratory and in the field. Investigations were continued to determine the influence of wood:water ratio, temperature, and duration of cooking on the alkali solubility of the product. From the field trials begun in April, 1953, soil samples were examined and pasture establishment observed. A heavy application of treated sawdust was found to induce nitrogen shortage where the nitrogen content was initially very low and to delay growth of pasture, although the recovery evident by the next autumn was quicker than with fresh sawdust. Nitrogen has been added in various quantities and its effects are being investigated. Further trial plots have been established in a second area in collaboration with the Victorian Soil Conservation Authority.

Methods have been sought for using micro-organisms in rapidly decomposing the non-lignin portions of finely-divided wood waste, leaving a residue suitable for use as a soil improver. Wood-destroying fungi have been isolated and tested, and investigations of the optimum conditions for their growth and for the decomposition of mountain ash sawdust have been carried out. To date some 42 samples have been tested, of which two have produced appreciable break-down of sawdust.

A study has been made of the optimum amounts of moisture and nitrogen for decomposition of mountain ash sawdust by *Coniophora cerebella.* After twelve weeks the caustic solubles were determined. Greatest decomposition shown by this test was obtained with 0.5 per cent. peptone and 100 per cent. water.

Examination of cases of fresh grapes packed in sawdust showed that their condition after storage in Sydney and after export to Singapore was as good as that of grapes packed in granulated cork. The suitability of sawdust for packing fresh grapes for export has thus been demonstrated. Packers and shippers are arranging shipments to establish acceptance by traders.

Hardboards were produced experimentally from mixtures of gelatinized fine sawdust and attrition-milled coarse sawdust. Conditions were found under which strengths comparable with those of commercial hardboards were obtained. Promising boards of attractive appearance and strength were also produced from water-cooked sawdust.

(*d*) *Sawing.*—Investigations with chain saws and circular saws were continued. The effect of height and hook angle of teeth in scratch type chains has been further studied. Preliminary experimental work on gouge type chains was commenced and improvement in performance was achieved by modification of teeth and gauges.

(*e*) *Standards.*—Collaboration with the Standards Association of Australia was continued on matters concerning timber standards. Chairman's duties were undertaken for several Sectional Committees functioning under the Timber Industry Committee and technical service rendered in drafting and reviewing proposed standards. The following Australian standard specifications were published by the Association: "Plywood for General Purposes", "Wood Treated with Lycticides", "Synthetic Resin Adhesives", and "Protein Adhesives". Interim specifications published were: "Poles", "Piles", "Heavy Engineering Structural Timbers", "Sleepers and Crossings", "Adhesives for Fruit Case Labels", "Tilers' Ladders", and "Nomenclature of Imported Commercial Timbers". Draft standards for crossarms of eastern Australian hardwoods were circulated for public critical review and progress made in the preparation of grading rules for radiata pine sawn timber, flooring, lining, weatherboards, and mouldings. A first draft revision of "Terms and Definitions used in Timber Grading Rules" was circulated for comment and more progress made in the revision of nomenclature. Comments were prepared on several draft British Standards.

Liaison was maintained with the Food and Agriculture Organization's Permanent Committee on Standardization and Utilization and membership continued in its sub-committees on grading. Comment was submitted on a first draft of the F.A.O. "Grading Rules for Sawn Hardwood" and a third draft of the F.A.O. "Grading Rules for Logs".

XV. BUILDING.

1. GENERAL.

The building research work of the Organization is undertaken mainly by the Division of Building Research, Highett, Victoria, which collaborates closely with the Commonwealth Experimental Building Station of the Commonwealth Department of Works in New South Wales. Research is directed towards the study of the more effective use of available materials, the adaptation of traditional materials to new constructional methods, and the development of new materials and building techniques for the improvement of both the functional aspects of buildings and the efficiency of methods of construction. The work of the Division is reported in this chapter.

Work on timber for construction purposes is concentrated in the Division of Forest Products (*see* Chapter XIV.). Work on house foundations is undertaken by the Division of Soils (*see* Chapter II., Section 4), and work on cement and ceramics by the Division of Industrial Chemistry (*see* Chapter XVIII., Section 3).

Division of Building Research.—The work of the Division has continued on similar lines to that of the previous year, but more time has been spent answering inquiries which, through the recovery of the building industry from the recession of 1952-53, increased by 26 per cent. to 3,400.

Close liaison has been maintained with the various branches of the building industry, the Standards Association of Australia, and the various Commonwealth and State Departments interested in building. As a consequence of the visit of an officer to Ceylon in 1952 under the Colombo Plan to report on the establishment of a modern brick and tile industry, contact has been maintained with the Ceylon Government regarding the implementing of the recommendations made.

The Division suffered a severe loss in the untimely death of Mr. B. M. Holmes, officer in charge of the Organic Materials Investigations, and this has led to a serious delay in the publication of the work on bituminous membranes for flat roofs. A research trainee has been sent abroad to study bitumen, with particular reference to its use in building, at the Road Research Laboratory in England and the Bataafsche Petroleum Maatschappij in Holland.

Lectures by member of the staff to students of the University of Melbourne and the Melbourne Technical College were continued; and in co-operation with other research bodies the Division contributed to the Architectural and Building Exhibition held in conjunction with the Sydney Convention of the Royal Institute of Architects.

2. Lightweight Aggregates.

(Division of Building Research.)

(*a*) *Expanded or Bloated Clays and Shales.*—Further work on expanded aggregates has resulted in a reduction in water absorption and density, and in harder and better vitrified surfaces. Satisfactory lightweight aggregate can be made from the blue Silurian shales that are exposed at the bottom of many of Melbourne's brick pits. Tests on one of these shales have shown that it bloats well without additives merely by firing the crushed shale in a rotary kiln.

Tests on concrete made with expanded aggregate produced in the Division have shown that although, as with ordinary concrete, the workability is increased by increasing the proportion of large particles in the mix, some material of less than 52 mesh is needed to prevent segregation.

(*b*) *Perlite.*—There is considerable commercial interest in the ultralightweight aggregate perlite and technical assistance on its manufacture has been given to several firms. A simple but efficient, indirectly fired, high speed rotary kiln for expanding the raw material, obsidian, has been built in the Division.

The mechanical properties of mixes of gypsum plaster and perlite have been measured. Strength, density, and expansion-contraction all decrease as the quantity of perlite in the mix is increased. The compressive strength and shrinkage of various mixes of perlite with Portland cement have been measured. An unexpected effect is the tendency of some lean mixes to expand after a time, due possibly to the presence of soluble silica or zeolitic minerals in the perlite.

3. Concrete Investigations.

(Division of Building Research.)

(*a*) *Theory of Rupture of Concrete.*—Information obtained from the study of the mechanism of the failure of concrete under load has led to a tentative theory of rupture of concrete in which the criterion of failure is a function of the shear-strain energy per unit volume and the volumetric expansion. Failure, here, is the stress at which cracking starts and, as was stated in the last Annual Report, this stress is much lower than the stress under which the concrete will break.

A theoretical study has been made of the stresses in and around an inclusion of one elastic material in a matrix of another, to assist with the work on the rupture of concrete and the effect of the properties of coarse lightweight aggregate on the strength of concrete.

(*b*) *Shrinkage Studies.*—It has been the practice for some time to take specimens for shrinkage measurements from any mixes that were being prepared. As the data accumulated in this way have several interesting features, a more thorough examination is being made, firstly, of the influence of gaseous carbon dioxide on the shrinkage of mortars, and secondly, of the factors affecting the shrinkage over the first 48 hours after mixing. It has been found that specimens stored immediately after demoulding for 28 days in gaseous carbon dioxide showed at four months about a quarter of the shrinkage of specimens stored in air. The crushing strength at 28 days of the former specimens was three times that of the latter. The second part of these studies concerns the shrinkage of specimens immediately after demoulding and was begun in order to find the most suitable datum for long-term shrinkage measurements. Contrary to expectations, it has been found that for many cements the shrinkage of concrete does not begin immediately after demoulding but some hours later.

(*c*) *Concrete-Reinforcement Bond.*—There is little information on the strength of the bond between concrete and steel reinforcement at 24 hours, and as this may influence the cracking of precast concrete products a short investigation of the problem was undertaken.

(*d*) *Cellular Concretes.*—Commercial interest in the manufacturing and use of foamed concrete has not been sufficiently great to justify the continuance of the project and it is now being concluded. However, the effect of the water: cement ratio on the strength and shrinkage of foamed concrete, and means for increasing the strength: weight ratio and dimensional stability of the material, have been studied.

Another lightweight material being investigated is cellular calcium silicate, an autoclaved mix of hydrated lime and silica flour. It has been found that for material with a dry density of 65 lb./cu.ft. (1:1.7:1.5 by weight lime: silica: water), cured by autoclaving for 4½ hours at a temperature of 350° F., a compressive strength of about 8,500 lb./sq. in. at an age of one day can be obtained.

4. Gypsum Plaster and Plaster Products.

(Division of Building Research.)

(*a*) *Fundamental Research.*—From a thermal and X-ray examination of pure synthetic gypsum there is some evidence that the conditions of precipitation influence the behaviour during dehydration. This may account for the variations which manufacturers find in gypsums from different sources.

It has been found that plasters retarded with citric acid fall into two classes, those in which the setting time increases continuously as time increases to a maximum and then decreases as the quantity of retarder is increased. Reasons are being sought for this behaviour, and also for the variations caused by different quantities of retarder in the time-interval between initial and final set.

Studies of the effect of particle size on the setting time of plaster have been hampered by the effects of the fractionation process on the plaster. The working of the plaster during shaking and stirring causes it to set approximately twice as fast as before agitation. This effect is important in plants handling plaster in bulk by means of screw conveyors, bucket elevators, &c., and the reason is being investigated.

Measurement of the consistency of plaster slurries is complicated by the progressive setting of the plaster, but it has now been found that when the standard slump consistency test is used the setting may be retarded by replacing part of the mixing water with alcohol.

Strength measurements made on plasters within 1-2 min. of the initial set and at intervals thereafter show that the development of strength follows the rise in temperature of the setting plaster very closely, the final wet strength being reached shortly after the temperature reaches its maximum.

(*b*) *Reinforced Gypsum Plaster.*—(i) *Wall Units.*—Short-term strength tests were carried out on the lintel sections of commercial precast reinforced gypsum wall units and the behaviour of two full-size slabs under long-term loading of 400 lb. per linear foot is being determined. Cracks appeared first at the ends of the 8-ft. wide lintel section of one of the full-size slabs and then at the centre of the lintel, which has deflected about ⅓-in. in 80 days.

Measurements of the elastic properties of gypsum plaster show that the stiffness and strength decrease with increasing amounts of water in the mix and that as a general rule the values of Young's modulus are less than those given in overseas literature.

(*c*) *Fibrous Plaster.* — (i) *Decoration.* — Previous investigations have not satisfactorily solved the problem of diffuse brownish discolorations on fibrous plaster decorated with water paint. This discoloration was believed to be due to hydroxides of iron which were leached to the surface by alternate wetting and drying of the sheet. Tests have now shown that 1 per cent. lime added to the plaster during sheet manufacture will prevent stains from forming even in the presence of large quantities of iron compounds.

The reason for "damp staining" of fibrous plaster is being investigated. Two experimental ceilings decorated with various paint systems have shown that in very humid weather some of the paints take on a damp appearance. The system most noticeably affected so far is kalsomine over glue size.

(ii) *Bulging of Plaster Ceilings.*—A trouble with fibrous plaster reported only from South Australia is the bulging downward of ceiling sheets between nailing points, usually during the first winter after erection. The sheets do not appear to have lost strength, the bulges being quite firm and rigid. The trouble appears to be associated with the plaster and samples brought from South Australia are being tested.

5. LIME AND LIME PRODUCTS.

(Division of Building Research.)

(*a*) *Correction of Unsoundness in Magnesian Limes.*—To test the performance of salt-treated magnesian limes several wall panels containing various limes with and without calcium chloride have been erected in the grounds of the Division and a manufacturer is testing the salt treatment method in the production of sand-lime bricks.

(*b*) *Standard Test for "Soundness" of Lime.*—None of the present Australian or overseas specification tests for "soundness" in lime appears to be entirely satisfactory and a simple standard test suitable for the detection of both calcium and magnesium unsoundness is being sought.

(*c*) *Sand-lime Bricks.*—The experimental walls now include panels of coloured bricks and mortars of different strengths and so far no water penetration or other trouble has been observed.

6. CLAYS AND CLAY PRODUCTS.

(Division of Building Research.)

(*a*) *Clay Research.* — (i) *Studies of Australian Heavy Clays.*—The preliminary survey of the structural clay products industry in Australia was completed during the year by visits to works and their deposits in and around Melbourne. Clays of the Melbourne area are now being investigated in the laboratory. The clay mineralogy and particle size distribution of the brickmaking clays of Ordovician age from west central Victoria are being studied also. Results so far show that the clay mineralogy is complex and that the complexity increases with the depth of the deposits. Kaolinitic and illitic clay minerals and quartz are the main constituents in the materials used at present but others, not yet identified, appear in the deeper layers.

(ii) *Mineralogy.* — Much differential thermal analysis and X-ray work has been done on samples of vermiculite and mixed-layer clay minerals, to obtain data for use in the preparation of the chapters on these clay minerals for the proposed publication on differential thermal analysis by the Clay Minerals Group of the Mineralogical Society of London.

Typical terra rossa and rendzina soils from the Division of Soils have been examined by differential thermal analysis (D.T.A.) techniques. The D.T.A. curves showed characteristic differences between the amounts of organic matter and the clay mineral in the end members of each group.

(iii) *Deterioration of Roofing Tiles.*—The study of the deterioration of terra-cotta tiles on roofs along the sea fronts of Victoria has been continued. Examination of damaged tiles from two inland Melbourne suburbs has shown that their deterioration is similar to that of tiles near the sea and the study has therefore been extended. Chemical and mineralogical studies of tiles have shown that the salt content, with which the damage has been suspected or being associated, is not necessarily the primary cause of the trouble.

(*b*) *Clay Technology.*—The industrial potential of clays from various sources have been assessed by examination in the pilot plant. Deformation under load and melting point determinations on several refractory clays from Western Australia are in progress.

The chief brickmaking raw materials of Sydney are the Ashfield Shales, which have always been dry-pressed for making bricks. It has now been shown that if these shales are ground sufficiently fine they give a material plastic enough to be extruded and good quality bricks may be made from them by the wire-cut process.

7. CAULKING COMPOUNDS.

(Division of Building Research.)

(*a*) *Cold Flux Mastics.*—Cold flux mastics, known in the United States of America as two-component internal-set-up mastics, are used extensively in that country for sealing joints in concrete canal linings. A study of the properties of these mastics and of how they may be duplicated with local materials is in progress.

The rheological or flow properties of the mastics are determined largely by the nature and proportions of the major components, mineral oil and bitumen, hence an extensive study has been made of dispersions of hard powdered bitumens in oils ranging from highly aromatic to highly paraffinic types.

On the basis of rheological measurements on dispersions of bitumen in oil, mastics have been formulated by adding asbestos fibre and/or powdered fillers to selected bitumen-oil systems. The properties of these mastics are now being studied.

(*b*) *Caulking Equipment.*—Pressure equipment for extruding mastic direct from the manufacturer's package was designed and constructed in the Division. Co-operative trials of the suitabilty of the equipment for caulking the joints of a large suspended floor were undertaken with a contractor.

8. BITUMINOUS ROOFING MATERIALS.

(Division of Building Research.)

(*a*) *Bituminous Adhesives for Built-up Roof Construction.*—Examination of the rheological properties of air blown bitumens of the kind normally used for roof bonding in Australia has shown that these may be less suited for use in roof bonding than the more highly blown bitumens of relatively high penetration. The latter have excellent pliability at low temperatures and good slump resistance at high temperatures.

The merits of building up a roof membrane with short lengths of felt, the ends being lapped in a spliced joint, have been studied. Spliced joints give the membrane greater flexibility by allowing shear in the bitumen between the laps.

(*b*) *Friction Between a Membrane and a Concrete Deck.*—Tests with loose-laid and solid-bonded membranes on concrete slabs and covered with paving slabs poured *in situ* indicate that solid bonding of the membrane to the deck does not present any greater risk of rupturing the membrane when cracks open in the deck than when the membrane is laid loose, as is often contended.

(*c*) *Experimental Roof Membranes.*—Inspections of the Division's experimental flat roofs and small-scale membrane specimens have continued. Where blown bonding bitumen was also used as a surface dressing it was unsatisfactory, showing severe cracking. Sections surfaced with coal tar pitch or with a very thick layer of clay-stabilized bitumen emulsion were reasonably satisfactory.

(*d*) *Field Investigations.*—Frequent inquiries on flat roofing problems continue to be received. A comprehensive report was made to the Commonwealth Department of Works on various bituminous roof maintenance and design problems in government buildings in the Australian Capital Territory.

An investigation on the source of leaks in a paved membrane of one of the Organization's own buildings was completed. At points of leakage shown by flooding tests, fissures in the membrane, obviously caused by small cracks in the underlying grading course, were found beneath the paving tile joints.

9. CONCRETE FLOORS.

(Division of Building Research.)

For some years the Division has been studying questions of comfort on concrete floors laid on the ground.

In examining the effect of concrete floors on the thermal characteristics of dwellings, the likely temperatures in winter inside typical Australian houses, both of cavity brick and of frame construction, have been calculated for two floor systems—one the traditional timber floor over a ventilated crawl space and the other a concrete slab laid directly on the ground. In unheated portions of both types of house the one with the timber floor will be slightly warmer in the early afternoon, whereas the one with the concrete floor will be warmer in the evening. In the heated portion there is no afternoon advantage with the timber floor, but the evening advantage with the concrete floor is greater.

When a concrete floor is laid on the ground there is a risk that on some sites moisture may penetrate the slab and adversely affect any impervious covering. Preliminary work has therefore been started to obtain information so that the need for a waterproof membrane on any site may be assessed.

10. THERMAL INVESTIGATIONS.

(Division of Building Research.)

Insulation is widely used in cold countries overseas to reduce the amount of heating required in buildings. The amount of insulation required under Australian conditions cannot be readily assessed since far less heating is needed and this only intermittently. However, the heating needed to maintain comfortable conditions in winter has been calculated for typical houses. From this, the saving made by insulation of various thicknesses and in various positions can be estimated and the optimum thickness of insulation determined. Charts relating this optimum thickness to the rate at which the cost of the insulation must be amortized, the relative costs of insulation and fuel, and the number of hours of heating, have been prepared for each capital city.

11. ARCHITECTURAL ACOUSTICS.

(Division of Building Research.)

The acceptability of echoes added artificially to both speech and music has been studied further. The acceptability had previously been thought to depend on an inherent property of the ear, but it has now been found that the relation between the echo level and delay, when the echo is acceptable, can be correlated with certain factors in the original sound irrespective of whether it is speech or music. Earlier results from both here and overseas will therefore reflect the acoustic environment in which they were obtained and this fact must be borne in mind when making deductions from them.

A quarter-scale model of a room, rectangular in plan, has been made with bounding surfaces of the same acoustical response as those in the room. The behaviour of the room and the model under various acoustic tests have been compared and the model duplicates the room response with good accuracy. Overall, the correlation is far better than that between subjective impressions of the acoustics of a space and objective measurements made therein.

Acoustic filter design and the analogous problem of electrical filters can, it has been found, be made much simpler by considering several similar discontinuities in series and applying the impedance tube method, in which the amounts of the incident sound reflected and transmitted from a discontinuity are measured. Charts have been prepared and published for use in cases where up to four similar discontinuities follow one another.

12. OTHER INVESTIGATIONS.

(Division of Building Research.)

(*a*) *Sprayed Vinyl Coatings (Liquid Envelope).*—Trials are being made of the weather resistance of sprayed vinyl coatings, known as "Liquid Envelope" or "Cocoon", which are being used to provide waterproof membranes on walls and roofs.

Specimens exposed in the open for about six months have shown no signs of deterioration and a laboratory specimen, designed to test the behaviour of coatings when subjected to movement as experienced in buildings, has so far withstood over 4,000 hourly cycles of stretching and recovery of 0.06 in. over a gap of ¼ in.

(*b*) *Pointing Materials for Sandstone Ashlars.*—Examination of Hawkesbury sandstone and four mortars showed that the rate of water absorption, hence the permeability, was much lower in the sandstone than in any of the mortars and therefore that, so far as the movement of soluble salts was concerned, the choice of mortar mix was not critical.

(c) *Stresses in Reinforcement.*—Stresses in the reinforcement, both in prestressed concrete beams and in precast gypsum lintels, were measured by electrical resistance strain gauges attached to the reinforcing wires before the units were cast. For the concrete beams it was possible to measure the stress applied to the wires, the loss of stress during vibration, cutting of the wires, &c., and the loss due to creep and shrinkage of the concrete over some months. This is probably the first time that such information has been obtained by direct means. For the gypsum lintels it has been possible to assess the extent of the bond between the gypsum and the reinforcement.

XVI. WOOL TEXTILES.

1. GENERAL.

An extensive programme of research has been undertaken with the aim of improving the use of wool as a textile fibre. This work is complementary to research in sheep husbandry, described in Chapters V., VI., and VII., which is aimed at increasing the quality and production of wool. The major aims of wool textile research are: (i) to increase the knowledge and understanding of the complex structure of the wool fibre; (ii) to use this knowledge to improve wool as a textile fibre, to improve technology in wool processing, and to utilize by-products more fully; (iii) to improve machinery used in wool textile manufacture. In these ways it is hoped to advance the position of wool as a competitor with synthetic fibres in the world markets.

The Organization's work in this field has been distributed among three Wool Textile Research Laboratories, as follows:—

(i) The Melbourne Laboratory at Parkville is responsible for fundamental chemical and biochemical work.
(ii) The Geelong Laboratory at Belmont is responsible for technological investigations.
(iii) The Sydney Laboratory at Ryde carries out research on the physics of wool and the physical and engineering aspects of wool processing.

The Division of Industrial Chemistry has continued a study of the constituents of wool wax and possible ways of utilizing them or their derivatives (*see* Section 4 of this Chapter). It is also studying the structure of proteins in relation to wool (*see* Section 10 of this Chapter). The Division of Entomology is continuing to study the digestive processes of wool-eating insects and larvae (*see* Chapter IX., Section 2).

Wool Textile Research Laboratories.—In the Melbourne Laboratory, research on the fundamental properties of the proteins of the wool fibre has been intensified, particular emphasis being given to perfecting methods for separating and analysing the various protein entities present in wool. In addition, liaison with the Divisions of Animal Health and Production and of Industrial Chemistry has been established to facilitate the application of established techniques to a wider range of research problems associated with wool production and processing.

At the Geelong Laboratory research has continued along certain major lines closely related to general problems of the industry. New research projects have commenced in the fields of weaving and dyeing. During the year a new building was completed and occupied, thereby permitting an increase in activities, particularly on processing problems where space is now available to accommodate the machinery required. The machinery area of the new building was used for staging a Textile Machinery Exhibition in April, at which some of the latest British worsted equipment was on display. This was well attended by representatives of industry, from both Australia and New Zealand. In co-operation with the Gordon Institute of Technology, a Wool Textile Research and Industry Conference was held in Geelong during May; over 150 representatives of industrial, research, and teaching organizations were present. More than 200 industrial inquiries were attended to during the year, covering a wide range of subjects. Contact with industry was also strengthened by the commencement of the *C.S.I.R.O. Wool Textile News*, the first issue of which appeared in June, 1954. Geelong mills have co-operated by assisting with the installation of textile machinery. In addition, some firms have kindly donated or loaned machinery so that certain research projects could be undertaken before the Laboratory's own equipment was delivered. The Gordon Institute of Technology has continued to make its facilities available as required.

The Sydney Laboratory has continued work on the physical properties of the wool fibre and of assemblies of wool fibres. The work on supercontraction in the Applied Chemistry Department of the New South Wales University of Technology has been continued.

2. RAW WOOL.

(Wool Textile Research Laboratories.)

(a) *Branding Fluids.*—L.B.E. Branding Fluid continued to be widely used by graziers, over 50,000 gallons being marketed by various firms during the present year.

With the co-operation of the Wool Industries Research Association, Leeds, it has been possible to trace back to the grower certain lots of wool which were causing trouble in manufacture owing to the presence of brands. The trouble was found to result from the use of certain of the older types of proprietary branding products. The manufacturers concerned were informed and have now discontinued the manufacture of these products in favour of the L.B.E. formula.

Further research is in progress to improve the recommended branding fluid so that it can be applied to wet sheep or under any conditions of rainfall without smudging. Very satisfactory results are being obtained in these experiments, but a complete account will not be available until large-scale field trials are concluded at the end of 1954.

(b) *Fellmongering.*—Liaison with the fellmongering industry has been maintained although fellmongering research has been discontinued. Numerous inquiries, principally on recovery of wool from sheepskin pieces, have been received. Digestion processes involving preliminary heat denaturation of the skin proteins have been widely adopted in Australia and overseas.

(c) *Solvent Degreasing.*—Two more large-scale combing trials were undertaken, and in each instance solvent degreased wool performed better in processing than that scoured by the usual methods, the weight of top produced being significantly increased.

The pilot plant has now been modified so that wool can be processed on it at much higher speeds, and large-scale tests are in progress using a higher speed and extremely short periods of treatment. Indications are that the plant should be capable of degreasing wool continuously in a period of the order of one minute.

(d) *Carbonizing.*—A preliminary survey of the contents of acid baths used in industry for carbonizing showed a very wide range of acid concentrations, even within a single plant. Samples of commercially carbonized wool were in some instances badly damaged, indicating the need for closer control of carbonizing processes. Studies have also been initiated on the kinetics of the reaction of sulphuric acid with wool and with cellulose. The effects of catalysts are being determined.

3. Recovery of Wool Wax.

(Wool Textile Research Laboratories.)

The flotation recovery process was installed in two additional plants during the year. Much assistance has been given to mills making new installations. In addition, a service has been provided to firms who desire heir scouring liquors analysed in order to assess uitability for flotation recovery. A complete analysis s being made of froth recovered from the flotation cells o ascertain the cause of variations in lanolin recovery etween froths from different plants.

4. Derivatives from Wool Wax.

(Division of Industrial Chemistry.)

The Division of Industrial Chemistry has made urther progress towards the identification of the ndividual components of the complex mixture that onstitutes wool wax. The aliphatic alcohols from he ester portion forming the bulk of the wax have een shown by fractional distillation in the spinning-and column to contain all seven members of the series f straight-chain alcohols of even carbon number rom octadecanol to triacontanol. These, together with he branched-chain alcohols previously isolated, bring he total number of aliphatic alcohols isolated to eventeen.

The design and development of a multiplate mole- ular still, for fractionating wool wax at very low ressures, is being undertaken with a view to studying he molecular weight distribution of the constituent sters, and possibly isolating some in a relatively pure tate.

Analytical methods for the study of wool-wax frac- ions obtained by chromatography have been further eveloped, and a convenient spectrophotometric method evised for the simultaneous determination of choles- erol and triterpenols in the alcohol fraction.

An officer of the Division has collaborated in work n an overseas laboratory which has resulted in the nal establishment of the structure and stereochemistry f the major triterpenoid constituent, lanosterol.

Attempts to convert individual constituents of wool ax to commercially valuable materials have been con- nued. Since the basic structure of lanosterol is osely similar to that of many naturally occurring ubstances of high biological potency, a programme as been initiated for the synthesis from it of analogues f these substances—in particular of some natural ormone types.

A convenient laboratory method for the isolation of holesterol from wool wax in a state of high purity has een perfected.

Some investigations into possible commercial uses or wool-wax acids have been carried out; a number f alkyd resins have been prepared from them which ay find application as components of automotive acquers.

5. Textile Processes.

(Wool Textile Research Laboratories.)

(*a*) *Yarn Manufacture.*—It has been found that the rictional forces of yarn around steel increase with nall cylinder diameters and angles of lap and at high elocities of rubbing. This is unexpected since from he usual laws of friction no variation should occur. he work is being extended to study the behaviour of iled yarns under conditions that would occur during rocessing.

(*b*) *Weaving.*—It has been shown that, for a plain weave cloth from 2/30's yarn, a reduction in warp yarn breaking strength of 15 per cent. is produced by abrasion and cyclic loading during weaving. Work is proceeding to ascertain which of the above two factors has the greater effect.

(*c*) *Bleaching and Dyeing.*—Research has commenced in the field of dyeing. Preliminary experiments have been carried out on the fastness properties of wool dyes as affected by different methods of application.

6. Modification of Wool.

(Wool Textile Research Laboratories.)

(*a*) *Application of Resins to Wool.*—Collaboration with industry has continued in processing wool commercially by the "Si-Ro-Fix" shrink-proofing method previously described.

It has been found that the presence of oils, soaps, &c., on wool can seriously affect the shrink-proofing action of resins applied to the fibre surface. This difficulty has been overcome in the present process by a combined treatment with resin and alcoholic alkali. The resin has also been applied from aqueous dispersion in order to avoid the use of alcoholic solution, but while felting shrinkage can be eliminated in this way, large quantities of resin are required. In an attempt to find a cheaper method of shrinkproofing, natural proteins such as casein are being applied to wool from aqueous dispersion, followed by a hardening treatment with formaldehyde. Pilot plant now installed at the Geelong Laboratory will enable further information to be obtained on commercial application to both woven and knitted fabrics.

(*b*) *Physics of Polymer Deposition.*—The way in which the resin distributes itself on the wool fibres during deposition for shrinkproofing is being examined by physical means. The effect of the resin on the mechanical properties of the fibre assembly is also being examined.

(*c*) *Mothproofing.*—Several methods have been developed for mothproofing wool which have proved satisfactory on a laboratory scale. These are now being tested on the industrial scale to ascertain any possible practical difficulties in application.

7. Physics of Wool and Fibre Assemblies.

(Wool Textile Research Laboratories.)

(*a*) *Mechanical Properties of Single Wool Fibres.*—The performance of wool both in wear and processing is very largely determined by the mechanical properties of the individual fibres. Study of these properties also gives information on the molecular structure and macrostructure of wool.

Work is continuing with single fibres on the stress-strain relationship and on creep and relaxation under a variety of relative humidity and temperature conditions. So far fibres have been studied in water over a range of temperatures and with extensions ranging from 5 to 20 per cent.; improved methods have been worked out for describing in mathematical terms the behaviour of wool fibres under constant load or constant extension. The work is being extended to embrace wool fibres under loads insufficient to remove the crimp. This particular range of extension is important, as it probably represents what mainly occurs to the fibres in a fabric under normal conditions of wear. Measurements are being made on fibres of different diameters and crimp formations as well as on crimped synthetics.

(*b*) *Regain of Wool.*—The amount of water in wool is referred to as regain, and is of great importance at all stages of manufacture from raw wool to finished goods. Its measurement is necessary as a basis for buying and selling on dry weight. Its control is important in processing for consistent production. In cloth the ability of wool to take up and release water plays a part in the comfort of a garment. A study of the mechanism by which the water is held will also throw light on the molecular structure of wool, and on why changes in regain have such a profound effect on the mechanical properties of the wool fibre.

The regain of small samples of wool, a few milligrams in weight and of known origin, is being measured very accurately over a range of temperatures and water vapour pressures. Further, a method has been developed, and is in use, for determining the rate at which the regain of a single fibre changes when the relative humidity of the air surrounding it is changed suddenly.

Two officers of the Fleece Analysis Laboratory of the Division of Animal Health and Production have for some time been studying the rate at which heat and water are gained or lost by small webs of wool in a moving air stream, and have been able to deduce how fast water diffuses through a wool fibre. The officers have recently joined the staff of the Sydney Laboratory, to continue the work in closer contact with the other studies on water in wool.

(*c*) *Mechanical Strains and Histology.*—Further examinations of longitudinal sections of wool fibres subjected to mechanical deformation were made, to determine whether the macrostructure played any part in the mechanical properties of the fibre.

(*d*) *Supercontraction.*—A study of the effect of surface-active agents on the supercontraction of wool has been in progress for several years by an officer working under Professor Alexander in the Applied Chemistry Department of the New South Wales University of Technology. The emphasis is now being placed on a study of the uptake of surface active and dye molecules by wool.

(*e*) *Yarn Structure.*—An investigation has started on the mechanical properties of yarns and the contribution of the individual wool fibres to those properties. A technique has been developed for making experimental yarns containing a few radioactive fibres. By means of an autoradiograph superimposed on a shadowgraph the position and shape of the fibres in the yarn can be seen during mechanical testing of the yarn.

8. HISTOLOGY OF WOOL FIBRES AND WOOL FOLLICLES.

(Wool Textile Research Laboratories.)

A general study of the fine structure of wool fibres has demonstrated the presence of two segments in highly crimped fibres. The arrangement of the two segments follows the crimp wave. Differences in the chemical and physical properties and in the origin of the two segments have been demonstrated, and suggest an explanation for the presence of crimp in wool fibres. Studies on wool fibre histology have been aided by the application of metal shadowing techniques for visual microscopy; in conjunction with the Division of Industrial Chemistry an electron-microscopic study of ultra-thin sections of wool fibres and follicles is being carried out.

9. WOOL PROTEIN CHEMISTRY.

(Wool Textile Research Laboratories.)

(*a*) ***Preparation and Properties of Wool Dispersions.***—It has been shown that about 65 per cent. of merino wool can be extracted as soluble proteins by alkaline solutions of potassium thioglycollate. Four main protein components have been identified by moving boundary electrophoresis; and by fractional extraction, one of these was obtained as a pure component representing about 40 per cent. of the total wool. Th molecular weight of this component as determine by the surface balance was shown to be pH-dependen and in alkaline solutions agreed reasonably with th value obtained using the Hepp type osmometer.

A modified wool, completely devoid of disulphid cross-links, has been prepared by repeated reductio and alkylation. Its solubility and other properties hav been studied. A similar disulphide-free wool protei prepared by ammoniacal extraction of wool treate with peracetic acid, has been fractionated and electr phoretic studies of the fractions and parent protei solutions made.

(*b*) *Amino Acid Composition of Wool Proteins.*- Complete amino acid analyses of Merino 64's, Meri 70's, and Corriedale 56's have been made. The tw classes of Merino wool differed significantly only their content of serine and cystine, whereas th Corriedale 56's was richer than Merino in alanin amide nitrogen, glutamic acid, and valine, and poor in arginine, cystine, and serine. The overall compos tion of the three wools was very similar. A simil analysis of the pure component from Merino 64 wool, described in Section 8 (*a*) of this chapter, h shown considerable difference in the amino acid conte as compared with that of whole wool, particularly the lower cystine content of the extracted protein.

(*c*) *Peptide Chemistry.*—Detailed knowledge of th properties of synthetic polypeptides should provi valuable information for explaining and utilizing th peculiar properties of wool proteins. A programm of research directed to the synthesis of cystine peptid is in progress.

(*d*) *Infra-red Spectroscopy.*—A Perkin-Elm model 12-C infra-red spectrometer has been modifi to eliminate interference from atmospheric wat vapour in the spectra of wool proteins and kerat fibres. Silver chloride and selenium polarizers hav been constructed and are being used to measure th infra-red dichroism of oriented protein structures su as wool, hair, and horn. A reflecting microscope h been designed and constructed to enable spectra be obtained from single fibres and from samples wool protein of the order of a few milligrams.

10. PROTEIN STRUCTURE.

(Division of Industrial Chemistry.)

The Division of Industrial Chemistry has continue its investigation of the structure of proteins; particular interest is the relationship between th structures of crystalline proteins and fibrous protei such as wool, hair, and muscle. New knowledge wi lead to a better understanding of the properties an function of proteins, and ultimately to the elucidatio of the processes by which fibrous proteins are form *in vivo.*

Electron-microscopical studies have received a ne impetus from recent advances in the technique ultra-thin sectioning. Sections of ferritin crystals o molecule in thickness have been cut and the electr micrographs show the arrangement of molecules in th lattice, which is not distorted by the sectioning. Th technique may reveal the architecture of prote crystals more clearly than is possible by any oth method. Examination of thin sections of muscle h extended our knowledge of the structure which w previously obtained by the examination of fragment material. The high degree of order which has bee revealed in the finer details of organization m permit of a correlation of muscular contraction wi structural changes observed in the electron microscop The structure of the wool fibre is also being invest gated by the technique of thin sectioning; an offic of the Wool Textile Research Laboratories is worki in the Division's laboratories on this problem.

X-ray studies of proteins are directed to the deter- nation of the crystal structure in certain amino ds, which are the building units of proteins. The ucture of aspartic acid hydrochloride has been ermined with such a high degree of precision that has been possible to locate the positions of the lrogen atoms.

On the chemical side an attempt is being made synthesize a polypeptide which will reveal the pro- sed helical structure of proteins but be sufficiently nple for its structure to be accurately determined X-ray diffraction. Some aspects of the chemistry L-glutamic acid have been investigated and the ssibility of a new method for synthesizing L-gluta- ne has been examined. Two new amino acids, 3- and minophthalyl-glycine, have been synthesized and own to polymerize readily; these polymers have ormal similarity to nylon.

11. DEGRADATION OF TEXTILES.

(Wool Textile Research Laboratories.)

(a) *Wool Damage by Bacteria.*—When moist fleece ol is piled loosely, "heating" of the wool, with con- erable damage, may occur. A study of the bacteria using damage to wool under conditions of high tem- rature and humidity has been made.

(b) *Digestion of Wool by Clothes Moth Larvae.*— contrast to the digestion of cellulose by the silver- h, it has been shown that bacteria have no part, direct indirect, in the digestion of wool by larvae of the thes moth, *Tineola bisselliella.*

(c) *Digestion of Wool by Proteases.*—The rate of gradation of wool by the enzyme trypsin has been ed to estimate the extent of changes in the structure the fibres after treatment with solutions containing emicals used in the processing of wool.

(d) *Fungal Degradation.*—Investigations on the ellulose" complex of the mould *Stachybotrys atra* ve been continued. Of the enzymes produced by is organism in shake culture, that responsible for the itial attack on cellulose and the non-adaptive ucosidase have received most attention. The ysiology of secretion of the latter enzyme is now rtly understood and the enzyme has been partially rified. There is evidence that many of the peculiar ysical and chemical properties of this enzyme are ared by other enzymes of the "cellulose" complex. programme of chemical modification of cellulose, th a view to increasing its fungal resistance, has own some initial success and is being continued.

12. GENERAL PROTEIN INVESTIGATIONS.

(Wool Textile Research Laboratories.)

(a) *Collagen.*—A study of the relationship between llagen and procollagen has been commenced. Work the biosynthesis of collagen, particularly in skin, is ojected.

(b) *Sheep Plasma.*—In conjunction with the Divi- on of Animal Health and Production, an electro- oretic examination of the plasma proteins of sheep being carried out to determine the changes in pat- rn obtained with sheep of different breeds and on fferent diets. It is hoped to obtain information on e transport of copper by plasma proteins and to late the electrophoretic patterns to the type and rate wool production.

(c) *Pure Proteins.*—In order to assess the signifi- ance of some of the properties of the wool proteins, ure proteins have been used as material for com- arative and developmental investigations. Surface ressure and surface potential measurements have been arried out on insulin films; an electrophoretic study has been made of the effect of cations on the mobility of bovine serum albumin; studies on the sequence of amino acids in the enzyme lysozyme, which were initiated at the Low Temperature Research Station, Cambridge, England, have been continued; a study of the action of oxidizing acids on proteins is in progress.

XVII. PLANT FIBRES.

1. GENERAL.

Only two plant fibres, cotton and flax, are produced commercially in Australia or the Australian Territories, although the possibilities of developing other fibres, such as jute, kenaf, hemp, ramie, and coir, are being investigated. The cotton industry, begun in Queensland about 30 years ago, has not yet reached a stage where it can contribute more than a small proportion of the country's requirements of this fibre. The Australian flax industry, greatly expanded under government control during the war, is now established on a modern and progressive basis and can supply the whole of the local demand. After the war, the Flax Research Section was established at Highett, Victoria, to meet the problems peculiar to the flax industry in Australia and to assist in its consolidation. With the subsequent expansion of the activities of the Section to include work on a number of plant fibres in addition to flax, it was later renamed the Plant Fibre Section.

Plant Fibre Section.—The activities of the Section embrace a wide field of both fundamental and applied research extending from agricultural and processing problems to the manufacture and utilization of plant fibre products. In addition to chemical, physical, microbiological, and engineering laboratories, the Section has fully-equipped experimental flax processing and spinning mills.

Close co-operation is maintained with the Flax Production Committee—of which the Officer in Charge of the Section is a member—in regard to both agricultural and processing problems, and also with flax spinners and weavers on various manufacturing aspects.

Investigations on fibres other than flax have been carried out mainly in conjunction with the Department of Territories and the Queensland Department of Labour and Industry.

2. AGRICULTURAL INVESTIGATIONS.

(Plant Fibre Section.)

Flax breeding projects carried out by the Victorian Department of Agriculture and the Waite Agricultural Research Institute in co-operation with the Plant Fibre Section have led to the development of a number of new flax varieties. These are particularly suited to local conditions and have high resistance to the rust races now prevalent in Victoria and South Australia. One of these varieties, Ventnor, now constitutes a considerable proportion of the flax grown in these States. There is always a danger of such varieties becoming susceptible to a new rust race and the flax breeding programme is being continued.

A study of the response of flax to various mineral fertilizers and the effect on the development of the fibre has given some interesting results, especially a marked response to nitrogen and potassium in combination.

Work has been continued on the evaluation of fibre from kenaf and manila hemp cultivation experiments in Papua and New Guinea.

3. Processing.

(Plant Fibre Section.)

(*a*) *Water Retting.*—During the year, mill-scale trials were completed on the so-called aerated retting of flax. These confirmed the laboratory tests and showed that with this technique the retting period could be almost halved. Some discoloration difficulties were encountered, but these appear to have been due to an uneven distribution of the air which is bubbled through the retting liquor while the ret is in progress, and should not be insurmountable. Laboratory tests to determine the optimum pH for retting activity are at present in progress; other investigations are concerned with the effect of adding various nitrogenous compounds to the retting liquor in an effort to further stimulate bacterial activity.

Investigations have been commenced on the water retting of coir.

(*b*) *Scutching.*—Experiments on the improvement of flax scutching machinery have yielded some highly significant results in laboratory tests and are now being extended to mill trials. Increased scutched fibre yields of 1-2 per cent. (based on the weight of straw) appear easily attainable from existing machinery with only minor modifications.

(*c*) *Preparing and Spinning.*—During the year the Section completed a comprehensive investigation of the effect of atmospheric temperature and humidity on the performance of various fibres during spinning. Although the properties of the final yarn may not be greatly affected by the atmospheric conditions, the behaviour of the fibre on the machines indicates that these conditions should be kept within certain well-defined limits. Apart from these tests the equipment has been fully employed on spinning trials of samples from various agricultural and processing investigations.

(*d*) *Utilization.*—A new project, begun during the year, aims at utilizing flax fibre from tow, of which there is a considerable surplus in this country, in the form of a staple fibre admixed with wool or cotton. Early results from this work are far from discouraging.

4. Microbiological Investigations.

(Plant Fibre Section.)

Basic studies on flax retting bacteria have been continued, including the investigation of such factors as nutritional requirements, sporulation characteristics, gas production, pectin utilization, and the products of carbohydrate metabolism. The information already obtained has made possible a much more complete understanding of the process of water retting.

5. Chemical Investigations.

(Plant Fibre Section.)

The study of the treatment of flax and other fibres with sodium hydroxide has been continued. This is the basis of the "boiling" treatment to which most flax yarn is subjected, and the work has now been extended to actual boiling tests on yarn. Cuprammonium fluidity determinations have been made on flax fibre processed in various ways to ascertain under what conditions cellulose degradation is likely to occur. Prolonged drying of the retted straw, as might occur during winter, and the presence of iron in the retting liquor were both found to have an adverse effect on the potential strength of the fibre.

6. Physical Investigations.

(Plant Fibre Section.)

Further investigations of the "knot efficiency" of various yarns, including flax, jute, and kenaf, have been made. This is the strength of a knotted yarn expressed as a percentage of the strength of yarn without a knot. The resistance of these fibres to fungal attack has also been studied more extensively. The desirability of "rotproofing" any vegetable fibre exposed to soil contact or to weathering has been amply demonstrated. Studies of the relationship between moisture regain and breaking strength of flax canvases have been extended to include a fabric made in Australia from decorticated kenaf for use in wool-pack manufacture.

XVIII. INDUSTRIAL CHEMISTRY.

1. General.

The Division of Industrial Chemistry represents the major concentration of chemical research within the Organization, although much chemical work is undertaken in other Divisions and Sections.

This Division was formed: (*a*) to promote greater technical efficiency in established industries; (*b*) to stimulate the establishment of new industries; (*c*) to encourage the use of raw materials of Australian origin; (*d*) to seek substitutes for imported materials; and (*e*) to find uses for by-products not utilized.

In addition to its basic chemical work, the main research activities within the Division deal with mineral utilization, cement, ceramics and refractories, organic chemicals, wool, and brown coal.

The Division's study of the constituents of wool wax and possible ways of utilizing them or their derivatives is described in Chapter XVI., Section 4. The Division is also studying the structure of proteins in relation to wool (*see* Chapter XVI., Section 10). The Division's work on the utilization of brown coal is described in Chapter XX., Section 7.

The work of the Organization's Tracer Elements Investigations Unit in the procurement and distribution of radioactive isotopes and the preparation of isotopically labelled components is described in Section 9 of this Chapter.

Division of Industrial Chemistry.—The Division was established in 1940. Since that time the research staff has increased continuously, but progress in recruitment of staff has always been in advance of progress in construction of laboratory buildings. The completion of a large new building towards the end of the year has permitted a general reallocation of laboratory space which will considerably relieve the position for most sections of the Division. It has also permitted the transfer to Fishermen's Bend of the Alkaloids and Stock Poisons group previously located in the Chemistry Department of the University of Melbourne. The Microanalytical Laboratory, conducted jointly by the University of Melbourne and the Division, will remain in the Chemistry Department of the University.

Once again numerous members of the scientific staffs of industrial firms and of other research institutions have spent periods from a few days to several months working in the laboratories at Fishermen's Bend. An interesting experiment has been the operation of a pilot-scale fluidized bed roasting unit as a joint project of the Division with the Mount Morgan and Mount Lyell mining companies.

2. Minerals Utilization.

(Division of Industrial Chemistry.)

Current work may be conveniently considered under two main headings. In the first group of projects the main objective has been to devise methods for the separation of one or more metals from the many extraneous substances with which they are normally associated in various Australian ores. These investigations, which are closely related to extractive metallurgy, have as their object the isolation of the metal or some convenient compound of it. Projects on hand relate to the extraction or chemical concentration of copper, uranium, zirconium, hafnium, chromium, thorium, and germanium.

A second group of projects involves the preparation and investigation of a wide range of inorganic compounds which may have potentially useful characteristics based on their physical properties. Lamellar compounds of graphite, synthetic semi-conducting compounds, dry lubricants, inorganic phototropic compounds, and certain lanthanon derivatives have formed the basis of research projects.

Research in X-ray crystallography, inorganic chemical analysis, pressure digestion reactions, polarography, and filter-air techniques have been undertaken concurrently with the above-mentioned investigations.

(*a*) *Extraction of Copper.*—An investigation was begun on methods of extracting copper from calcined chalcopyrite concentrates produced in a fluo-solids reactor (*see* Section 8 (*c*) of this Chapter). The experiments in progress are designed to find the conditions for leaching the maximum of copper and the minimum of iron and other elements from the calcine. It is also necessary to ascertain the best conditions for winning the dissolved copper from the resulting solution by electrolysis, having regard to purity of the product, cost of electric power, and utilization of existing plant. The efficient disposal of considerable quantities of by-product sulphuric acid has also to be considered. The work has been undertaken on behalf of the Mount Lyell Mining and Railway Co. Ltd. and Mount Morgan Ltd., who have provided financial assistance.

(*b*) *Uranium Extraction.*—Leaching tests have been continued on various types of ore from Rum Jungle, Northern Territory, particular attention being given to those ores which give comparatively low extraction of uranium under preferred conditions but which give a normal yield after roasting at 350-450° C. The improved filtration characteristics of calcined ores have also been studied. Examination of ores from new localities at Brock's Creek, Edith River, and Adelaide River, Northern Territory, has been made to determine their amenability to the leaching process proposed for Rum Jungle ores.

Studies on the recovery of dissolved uranium by chemical methods have been continued with emphasis on procedures involving selective precipitation by magnesia on both ion exchange eluates and crude leach liquors. Various phases of anion exchange recovery of uranium have been studied in detail, particularly with regard to adsorption and elution equilibria, the effect of phosphate in ion exchange, and the effect of various contaminants on elution efficiency. Work on the development of a continuous ion exchange process has been continued. Settling and filtration problems associated with uranium extraction have been investigated in detail with particular reference to the use of additives, and improvements leading to a threefold reduction in the filter area required have been effected for the most difficult ore studied.

(*c*) *Zirconium-hafnium Separation.* — Interim reports on the process developed for separating hafnium and zirconium have aroused considerable interest on the part of several overseas institutions. Preliminary pound-scale tests have been carried out and applications for patents have been lodged in Australia, Great Britain, and the United States. Equipment has been designed which will make the removal of hafnium an integral part of the large-scale process currently used in America and England to produce hafnium-free zirconium. It is expected that pound-scale quantities of hafnium-free zirconium compounds will be available by the end of 1954.

The raw material for the work on zirconium is the zircon sand concentrate obtained from the beach sands of Australia's north-eastern coastline. These sands represent the world's richest natural concentration of zircon. An efficient process for converting it from the silicate form to the anhydrous chloride on a pound scale has been set up and ample stocks of hafnium-bearing zirconium chloride for subsequent separation have been accumulated.

Increased interest in the lower halides of titanium has directed attention to the incompleteness of the information available on the analogous compounds of zirconium. Accordingly, a programme of basic research into the properties of zirconium di- and trichlorides has been commenced. In preparation for similar work on the corresponding iodides a method has been developed for converting zircon to zirconium tetraiodide.

(*d*) *Thorium Extraction.*—Monazite sand is recoverable as a by-product in the separation of titanium and zirconium minerals from the heavy sands of the beaches of eastern Australia. Improvements in the chemical processing of monazite for the production of various lanthanon compounds and thorium derivatives have been the object of investigations made for several years past. Work on the extraction of thorium by an acid process has now been completed and satisfactory methods have been evolved for the production of commercially pure thorium nitrate. For this acid method, a much smaller number of stages are required than in commercial methods formerly recommended and in other respects it is generally simpler. An alternative process for thorium extraction, using an alkaline method, has also been studied but it appears that in Australia it would be somewhat more costly than the acid process. These methods for isolation of thorium have been brought to the attention of possible producers in this country.

(*e*) *Germanium Survey.*—The use of germanium in electrical transistors has greatly stimulated the search for sources of this element and, although sporadic examination of various Australian flue dusts have been made, no systematic survey of possible sources has previously been undertaken. A wide range of flue dusts from metallurgical works and coal-burning and coke-making plants has accordingly been collected for chemical examination. Possible mineral sources of germanium have also been included in the survey. Some attention has been given to several sources of error in the chemical estimation of germanium and improvements in the analytical technique have been devised. In common with experience elsewhere, the samples have already shown a very wide distribution of small amounts of germanium, but as yet no notable enrichments have been located. Flue dust from producer gas plants has given the highest relative figures. The Coal Research Section has assisted in this survey by supplying a number of samples of flue dust.

(*f*) *Scandium.*—Preliminary work was undertaken on the separation of small amounts of scandium from the waste liquors resulting from the processing of davidite ore for uranium in South Australia. Tracer element techniques using radio-active scandium and ion exchange procedures were employed and, although small quantities of scandium compounds were recovered, the result was unsatisfactory. This work was postponed pending a more detailed examination of certain of the chemical reactions of scandium which are imperfectly known at present.

(*g*) *Electrochemistry of Chromium.*—Studies were undertaken on the conditions necessary for the electroreduction of hexavalent chromium solutions, knowledge of which is of importance in the electro-winning and electroplating of chromium and in the use of chromates as corrosion inhibitors and organic oxidants. The hydrogen chromate ion has been shown to be much more easily reduced than the normal chromate ion and to play an important role as an intermediate product. The production of this intermediate is a fast ionic reaction determined largely by the conditions which prevail in the immediate vicinity of the electrode. By the use of the polarograph, it has been found possible to obtain an estimate of the speed of this reaction and to develop a method which can probably be extended to other ionic reactions.

(*h*) *Hydrometallurgical Investigations.*—A series of laboratory investigations has been made on the autogenous production of dilute sulphuric acid by the oxidation of pyrite in the presence of oxygen or air and water, under pressure at temperatures of about 200° C. Under these conditions certain ores are amenable to hydrometallurgical leaching of their metallic components as soluble sulphates. The pyrite may be added to the system or may be an integral part of the ore or concentrates subjected to leaching. Modification of the conditions affords opportunity for selective hydrolysis of certain of the resultant sulphates, thus leading to a high degree of specificity of leaching for some metals. This work is to be continued on a larger scale.

(*i*) *Lamellar Compounds.*—Recent work on lamellar compounds of graphite, which resulted in the definition of criteria governing the formation of many new molecular compounds of this type, has been extended. Theoretical investigations have led to the important conclusion that molecular intercalation should also be shown by substances other than graphite provided that they comply with several crystalline and electronic requirements. Experimental confirmation of the general nature of the molecular intercalation phenomenon, as shown by graphite, has already been obtained with boron nitride, aluminium dichloride, and chromium trichloride. Other potential host substances are being examined.

This understanding of the mechanism of intercalation in graphite has not only provided highly specific methods of separation and purification of inorganic compounds but has led also to the recognition of a new type of reaction likely to be of value in the study of other heterogeneous reactions in the solid state.

(*j*) *Lanthanon Compounds.*—In addition to studies on the carbides and iodides of thorium which are relevant to the metallurgy of that element, work was continued on the fluorides of cerium. Ceric fluoride, which is of potential use both metallurgically and as a reagent in certain organic reactions, was synthesized by processes involving either static of fluid bed conditions with gaseous hydrofluoric acid, as distinct from processes using elemental fluorine. Syntheses using bromine trifluoride were also employed. Preliminary work on the synthesis of praseodymium fluoride was also undertaken.

(*k*) *Chemical Crystallography.*—The investigation of minerals and synthetic inorganic compounds with defective molecular structures has continued. Work on the electrical properties of semi-conducting layer compounds has been carried on, while the dielectric absorption spectra of certain synthetic framework compounds have been examined at the Division of Electrotechnology. The structure of hydrohetaerolite has been determined by Fourier methods of X-ray analysis; work has also commenced on the properties of the non-stoichiometric sodium vanadates.

(*l*) *Titanium Compounds.*—The phototropic darkening of synthetic titanium dioxides when contaminated with iron oxide has been known for some time. On irradiation a tan colour develops and this subsequently fades in the dark. A detailed study of this phenomenon was undertaken and it was shown that chromium, nickel, and copper, in addition to iron oxide, were particularly active in producing a phototropic effect on titanium oxide. To a lesser extent certain of the rare earths or lanthanons, lead, manganese, and antimony were effective. The phototropic phenomenon has been considered to be due to the impurity entering the rutile lattice and undergoing an ionic change there. It has now been shown, however, that although some of the rutile modification of titanium oxide must be present before light sensitivity occurs, the most intense coloration, with iron, develops for the smallest conversion of a pure anatase modification to the rutile form. Furthermore the presence of moisture has now been shown to be essential for the colour change. This has pointed to a chemisorption process being involved. This concept has been substantiated by work on the other impurities mentioned, which are readily absorbed on synthetic rutile and depend on moisture for their function. A theory has been advanced to explain the action, and in the light of this theory host oxides other than titanium dioxide have been tested and found to give rise to similar effects. Among these are oxides of aluminium, tin, and tantalum. In addition to its theoretical considerations, this work has an important bearing on the colour and stability of many inorganic pigments.

Apart from the phototropic studies mentioned above, investigations were also made on the synthetic sulphides of titanium and zirconium. The former has been found to be a relatively good conductor of electricity with semi-conducting properties and its application to various electrical uses is being considered. These sulphides are graphitic in nature and have shown lubricating qualities which are being further studied.

3. CEMENT AND CERAMICS.

(Division of Industrial Chemistry.)

Current projects fall into two groups (i) an investigation of factors which influence the settling and hardening of portland cement, the durability of concrete, the mechanism and application of air-entraining agents in concrete, and the evaluation and use of pozzolanas in blended cements; (ii) the study of the physics and chemistry of clays to provide the necessary scientific background for the solution of problems associated with the use of clays as such or as manufactured products.

The Division is continually being called upon by both government authorities and industry for advice on the suitability of raw materials, on the diagnosis and elimination of faults in manufacture, and on problems occurring during use of the manufactured products.

The Division has received both financial and practical assistance from the Cement and Concrete Association of Australia.

(*a*) *Cement and Concrete.*—The investigation of the mechanisms of setting and the development of strength in hydrating cement has been continued. Although this work is necessarily slow, considerable progress has been made with a study of the effects of additives in the solution phase of cement paste, and their effects on physical properties such as volume stability, setting time, and strength of hydrating cement.

Although air entrainment in concrete has become a well-recognized and much-used technique, comparatively little is known of its basic mechanism. Were this known, it would be possible to predict the effect of air entrainment on the properties of cement pastes and the durability of concrete. Studies of the action of surface-active agents in cement paste have enabled a general theory of their action in promoting air entrainment to be postulated and it is now being tested n relation to concretes and mortars.

Investigation of the various mechanisms of expansion and shrinkage cracking has been continued and equipment has been developed for the study of the formation and propagation of cracks. Problems arising from the development of cracks are of considerable economic importance; damaged structures do not function satisfactorily, are costly to maintain, and are difficult to repair effectively.

Work has also commenced on the effect of various cycles of different conditions of exposure on the durability of concrete.

An examination of the behaviour of pozzolanic materials and of blends of pozzolanas and portland cement has been continued. Several Australian materials comparing favourably with one used extensively overseas have been studied and there is little doubt that there are many more local deposits of materials that are either naturally pozzolanic or in which pozzolanic properties can be developed. Considerable success has been achieved in increasing the rate of gain of strength as well as the ultimate strength of blended cement mortars. The use of these techniques would enable blended cements to be used satisfactorily in mass concrete and in certain types of concrete products with a considerable reduction in costs.

During the year many organizations have made use of the Division's specialized equipment or sought advice on a variety of problems such as the manufacture and behaviour of cements and concrete products, the diagnosis and elimination of the causes of deterioration, and methods for restoring damaged structures.

(*b*) *Cement-kiln Refractories.*—Investigations have been continued of the factors which, by causing mechanical stresses, decrease the life of the linings of rotary cement kilns. A study of operating kilns showed the beneficial effects of changes in design, such as the provision of stiffening rings. Investigation of the chemical and physical interaction of clinker and refractory lining has continued, especially in regard to the mechanism by which clinker adheres to the lining. This adhesion is necessary for the successful operation of conventional cement kilns. Parts of this latter investigation have been in co-operation with the Geology Department of the University of Adelaide.

(*c*) *Gas Works Refractories.*—The deleterious effects of heavy steaming on the refractories of continuously operated vertical gas retorts have been further studied. The tendency for increased production of ash, hence for increased slagging, reported by retort operators has found confirmation in laboratory studies. It has been further shown that the gases present in such circumstances may cause embrittlement of the refractories, but the practical significance of this observation has still to be assessed.

(*d*) *Survey of Clay Resources.*—Further ceramic and refractory clays from Western Australia have been examined, with special regard to possible expansion of local industry. The investigation of Queensland clays has been continued, and at the request of industry certain deposits have been evaluated for use in the production of sanitary-ware bodies and others for bleaching properties.

(*e*) *Clay Mineralogy and Related Studies.*—During the year considerable advances have been made in fundamental studies of the ways in which water molecules interact with the surfaces of clay mineral particles. Information of this kind is required in order to increase control over the behaviour of clays in plastic and slip form. Investigations by X-ray diffraction methods of the normally hydrated state of the mineral vermiculite have been extended to a condition of very low hydration, in which a layer of water a single molecule thick covers the mineral surfaces. The relationships observed are quite different from those of the condition, reported last year, in which a layer of double this thickness is associated with similar surfaces. From this work a picture is gradually emerging of the orientation and re-orientation of water molecules which take place as increasing amounts of water are added to a dry clay. The exchangeable cations present in this complex may profoundly influence the configuration assumed by the water molecules, and intensive study of this aspect of the problem is now required.

(*f*) *Silica for Refractories.*—Further studies of unexploited silica deposits in Australia, and the production of bricks on a pilot-plant scale, suggest that silcrete bricks could be produced in Australia. Silcrete in a special type of quartzite mined in South Africa for the manufacture of silica bricks. These bricks have such excellent properties that the rock is at present imported into the United Kingdom for their manufacture. Silcrete bricks have been used chiefly in steel furnaces but are of potential value in glass tanks and gas retorts. Hence they are of interest also in connexion with the project on gas retort refractories.

Attempts are being made also to modify conventional manufacturing procedure so that bricks can be made from ordinary quartzite with the properties of those made from silcrete.

(*g*) *Whiteware and Related Investigations.*—There have been further studies of the effects of processing operations on the microstructures of clays and ceramic bodies and on the relationships of microstructure to manufacturing problems and faults. Thus an investigation of the effects of rotational rolling on the structure of a ball clay has demonstrated clearly how differential drying shrinkage is related to the orientation of the particles. If the processing operation is such that orientation varies within the same piece of ware, drying strain is to be expected. An incidental result of the study of rotational rolling has been the demonstration that a tube can be made in this way, as well as by the conventional method of extrusion; both these methods have long been used for the production of metal tubes. Observations are being made also on the "memory" of clays. This little-understood effect is well known to potters and may cause distortion of the ware.

Work on the melting of feldspathic fluxes has continued. Such fluxes are widely used in bodies and sometimes in glazes. Added knowledge of the melting behaviour could lead to economies in their use and could indicate the optimum conditions for producing ware of specific properties, such as controllable porosity.

(*h*) *Special Ceramics.*—Special oxide ceramics and ceramic metal compositions are being studied. These are of interest in a diversity of fields, such as in the manufacture of high-temperature jets and of turbine blades, and in the production of atomic energy.

(*i*) *Adelaide Ceramics Laboratory.*—This Laboratory is operated in conjunction with the South Australian School of Mines and Industries. Its advisory service and practical assistance continue to be much in demand in relation to local deposits for the manufacture of structural products and of refractories.

4. FOUNDRY SANDS.

(Division of Industrial Chemistry.)

The laboratory is situated in the Metallurgy Department of the Melbourne Technical College. It is equipped for specialized testing of moulding sands employed in both ferrous and non-ferrous foundries, and among its major activities are testing sand samples submitted by industrial firms and advising on sand conditioning and control procedures. A catalogue of sand deposits adjacent to the principal cities of Australia is maintained and during the year many samples from additional potentially useful deposits have been examined. In the search for new sand deposits, particular emphasis has been placed on sands suitable for shell moulding.

An advisory service is provided for foundries on general metallurgical problems. Inquiries dealt with have come from most of the major industrial centres of Australia and have been concerned with many different aspects of foundry metallurgy. Numerous minor laboratory investigations have been undertaken in the course of this advisory work.

Developmental work on the use of Australian clays in the preparation of synthetic moulding sands has continued.

5. PHYSICAL CHEMISTRY.

(Division of Industrial Chemistry.)

The research programme is chiefly concerned with the conservation and use of water and the properties of surfaces and of fluids. Fundamental studies include studies of carbon and charcoals, of chemical reactions at high pressures, and of thermodynamic properties important in distillation. Applied investigations include the selective flotation of minerals, the removal of salt from water, the control of evaporation of water under natural conditions, and the use of fillers in rubber.

(*a*) *Properties of Liquids.*—This programme has as its fundamental objective the precise measurement of thermodynamic data which are important to the chemical engineer in the design of industrial equipment for distillation. Equilibrium values between vapour and solution for mixtures of polar liquids have been measured at various temperatures and pressures. The systems studied were ethanol-benzene, carbon tetrachloride-acetonitrile, and benzene-acetonitrile. Heats of mixing are also measured.

At the same time theories are being sought whereby these data may be predicted. This theoretical work has included the effect of electrostatic interactions and the problem of refining the "cell" theory for mixtures. A new theory has been developed to explain the physical properties of liquids and gases whose molecules are complex but are effectively spherical and non-polar.

(*b*) *Chemical and Physical Effects of High Pressure.*—The increasing use of high pressures in industrial chemical processes has emphasized the need for a basic explanation of why some chemical reactions are greatly affected by pressure. At the Division's High Pressure Laboratory in Sydney an extensive series of measurements of the rates of organic reactions at pressures up to 15,000 atm. has been made. The measurements show that those reactions which produce ions from neutral molecules are assisted by pressures, whereas the converse reactions are suppressed. A satisfactory theory of these effects has been obtained and to test these over a wider range the pressures are to be raised from 15,000 to 50,000 atm.

An earlier series of measurements of the behaviour of imperfect gases at low pressures has been extended to include mixtures of two gaseous compounds. The results show that, in general, there is no simple method of deriving the properties of a mixture from those of its components.

(*c*) *Mass Transfer.*—Industrial practice frequently requires the transfer of a substance from one liquid to another (solvent extraction). By a study of the behaviour of individual liquid drops in an hydraulic tunnel it has been found that the efficiency of extraction depends greatly on the extent of movement within a droplet. This movement, in turn, is governed almost entirely by traces of surface active impurities which cause surface tension gradients under dynamic conditions.

A new extraction process using solvents has been devised for separating chemicals. Solvent extraction processes operating continuously are most suited to large-scale operations. In Australia, where the scale of operations is relatively small, batch operation is to be preferred. The new process operates analogously to a batch distillation unit and is versatile in that the one column can separate a variety of different mixtures, each of variable composition and size. The separation of some alkaloids has been used to demonstrate the process. It is being investigated by several industrial organizations.

(*d*) *Flotation of Cassiterite.*—Because of the low recoveries in treating certain Australian tin ores, research has been undertaken with the object of developing improved methods of treatment. A flotation process is being developed for an ore from Maranboy, Northern Territory.

The variables affecting the flotation of cassiterite and the associated minerals have been tested in small-scale flotation machines. Careful attention to the dispersion and removal of finely divided material (slime) has been necessary.

(*e*) *Flotation of Wool Wax and Sugar-cane Wax.*—Following the successful operation of the first commercial plant using flotation to recover wool wax from wool scour liquor, other plants are being installed. Applications for patents have been lodged in several countries.

The principles of the process for recovering wool wax have been applied to the mill juices from sugar cane, and preliminary experiments at a sugar mill have shown the feasibility of recovering sugar-cane wax by flotation.

(*f*) *Fillers for Rubber.*—The long-term objective of this work is to find reinforcing fillers from Australian raw materials. To do this it is necessary to find why fillers can impart desirable properties to rubber. Three major points have been established during the year. Firstly, it has been shown that the filler is linked chemically to the rubber. Secondly, the new network which forms controls the majority of mechanical properties, such as modulus, hardness, and resilience of the filled rubber compound. Thirdly, the most important property of abrasion resistance has no simple relation to the network as such but is probably determined by the kind of linkage between the filler and rubber.

(*g*) *Continuous Adsorption Processes.*—The continuous process for ion exchange (described in the last Report) has been successfully operated as a water-softening unit. The process is now being applied to the separation of a metal ion from a pulp consisting of an ore and liquor. In the usual process, which is a batch operation, it is necessary to filter the pulp to obtain a clear liquor, otherwise fine particles of ore clog the bed of resin. The continuous process may be applied to ore pulps which cannot be filtered.

(*h*) *Conservation and Use of Water.*—Despite the Division's adverse report (1953) on the use of thin films (monolayers) of long-chain alcohols to prevent water evaporating, more detailed research, particularly out of doors, has shown natural evaporation to be retarded by 30-80 per cent. Important factors are the depth of water and the method of spreading the film. In co-operation with the Section of Meteorological Physics a number of small-scale tests have been made with very promising results. In the summer of 1954-55 it is intended to conduct large-scale experiments.

The need for water low in salt content for agricultural and domestic purposes is high in Australia. Much saline water is available which cannot be used even for stock. A survey has been made of existing processes and it has been decided to investigate electrochemical methods of removing the salt. One such process, which is being developed overseas, employs membranes which have the disadvantages of high electrical resistance and high cost. Work in hand is aimed at avoiding these difficulties.

(*i*) *Carbon.*—Amorphous carbon is a substance of great industrial importance. As cokes and chars it is a major raw material for the fuel and steel industries; as carbon black, incorporated in rubber, it makes possible a serviceable tyre; as activated carbon it has widespread use in gas-masks and throughout the chemical industry for removing colour and vapours; and it is widely used in the electrochemical industries. Despite this, its many chemical peculiarities have never been satisfactorily accounted for and carbon technology is essentially empirical.

The significant finding of the investigation has been that there are two major types of carbon, depending on the heat treatment. At one extreme the carbon acquires properties characteristic of a quinone and at the other the properties of a hydroquinone. Structures intermediate between these are possible and have pronounced semi-quinone properties. It now appears possible to account for all the major features of these carbons. The practical implications of these findings are being explored.

6. CHEMICAL PHYSICS.

(Division of Industrial Chemistry.)

Work has been continued on four main projects: (i) protein structure investigations; (ii) chemico-physical studies of the defect solid state; (iii) determination of molecular structure and energies; (iv) the development of specialized instruments and techniques. It has been necessary to carry out a considerable amount of work outside the scope of these projects, since the Division's specialized techniques have been applied to problems submitted by industry, the universities, medical institutions, and other parts of the Organization. Several guest workers have been accommodated for various periods during the year, either for the purpose of collaboration with officers of the Division or for training in the use of specialized techniques.

It is becoming increasingly evident that Australia's growing demands for scientific instruments for national defence, industry, and scientific work have created an urgent need for an Australian scientific instrument industry. It is believed that the Division's experience in the design and construction of new types of instrument will make a valuable contribution to the development of such an industry. Enthusiastic support was given to the Exhibition of Scientific Instruments organized by the Australian Branch of the Institute of Physics, which was held in Melbourne in March, 1954. The following instruments, which were designed and made by Divisional staff, were exhibited: a mass spectrometer, an electron microdiffraction camera, a microtome, and an atomic absorption spectrophotometer.

(*a*) *Protein Structure Studies.*—The investigation of both crystalline and fibrous proteins has been continued with the object of establishing the function, and ultimately the mode of formation, of fibrous proteins such as wool *in vivo*. This work, which includes the study of amino acids by X-ray methods, and the synthesis of polypeptides, is described in Chapter XVI., Section 10.

(*b*) *Chemical Physics of the Solid State.*—It is now generally recognized that imperfections and defects in solids are responsible for many important properties of materials, including those properties which make possible such articles as transistors, television screens, fluorescent lamps, and dry rectifiers. They are the operative factors in many processes in which a solid reactant takes part. The object of the current work is to obtain information on the nature and properties of defects in solids in order to understand their role in physical and chemical processes.

To investigate the electronic energy levels in phosphors, the optical constants of thin evaporated films of zinc sulphide have been determined. The methods developed are applicable to other materials which can be evaporated. The apparatus for investigating the luminescent properties of solids by periodic excitation has been further developed. This apparatus provides a powerful method of testing any postulated theory of the processes responsible for luminescence.

Studies of the oxidation of metals have been made, to establish the role of defects in the oxide produced. Some growth phenomena not previously observed have been studied.

Electron diffraction studies of gold containing small amounts of dissolved oxygen have clearly shown how gas atoms may be incorporated in a metal lattice.

(*c*) *Molecular Structure Studies.*—The determination of molecular structure and the evaluation of the mechanisms involving molecular processes are fundamental to most problems in chemistry, biology, and biochemistry. The development of new and more powerful experimental techniques has played an important part in this work; these are discussed in detail in Section 6 (*d*) of this Chapter.

(i) *Structure Analysis by X-ray Diffraction Methods.*—The analysis of the structure of aspartic acid hydrochloride is referred to in Chapter XVI., Section 10. This work showed that photographic methods of intensity measurement were sufficiently accurate to yield a precise structure determination, provided suitable corrections for asymmetrical thermal motions were made.

The structure and molecular configuration of isocryptopleurine, a derivative of the alkaloid cryptopleurine, have been completely determined. A new technique enabled the complete analysis to be made without any assistance from chemical data or knowledge of bond angles and bond lengths. This X-ray analysis is the first in which the structure of a complex organic molecule has been determined with no chemical information other than the empirical formula.

The study of vermiculite has included the X-ray analysis of partially dehydrated magnesium-vermiculite, a structure which involves only one sheet of water molecules between each pair of silicate layers.

(ii) *Structure Analysis by Electron Diffraction Methods.*—An investigation has been made, using Fourier series, of the effects on structure analysis of several factors, including the finite curvature of the Ewald sphere and phase shifts which occur when electrons are scattered by heavy atoms. Experimental methods of overcoming these effects have been devised and are being tested.

Measurement of the fine structure of selected spots in patterns from cubic MgO crystals has demonstrated the variation of the apparent inner potential of a crystal with depth of penetration of the electron beam.

(iii) *Spectroscopic Studies of Molecular Interaction.*—Spectra of iodine in solution have been studied as a means of obtaining data on the nature of the interactions between molecules in solution. A more satisfactory interpretation of such spectra has now been found. As an adjunct to this work the assignment of the electronic energy states of iodine has been revised and potential energy curves have been computed.

An officer of the Division, located in the Chemistry Department of the University of Western Australia, has continued to work in collaboration with Professor N. S. Bayliss on solution spectra in the vacuum ultra-violet region.

(iv) *Molecular Ionization Potentials and Bond Energies.*—The techniques of measuring ionization efficiency have been extended and it is now possible to record directly the second differential of the ionization efficiency curve for any ion fragment. It has been possible to determine the upper energy states of a wide range of simple molecules by electron impact methods; this new field of research has been called "electron spectroscopy".

A new method of reducing the energy spread in the ionizing electron beam has been devised and is expected to yield a tenfold increase in resolution.

(v) *Mechanism of Molecular Decomposition.*—The study of the mechanism of molecular decomposition is of basic importance in many chemical processes, and photochemical techniques provide a powerful method of attack. Studies of the photolysis of ketones have continued, using the mass spectrometer as an analytical tool. It has been shown that the appearance of the intramolecular mode of the photochemical decomposition of aliphatic ketones can be predicted from the structure of the ketone. A correlation has been found between the mass spectrometric cracking pattern of a ketone and its photochemical decomposition by rearrangement. Such correlations may yield information about the excited electronic states of polyatomic molecules.

(vi) *Theoretical Studies.*—The electrostatic method of calculating the properties of molecules has been further developed and it has been established that it can be applied directly to molecules for which the valence states of the constituent atoms are known. For molecules where the appropriate valence states are unknown a direct calculation by the electrostatic method appears to be impossible, but the method may be used to relate experimental energy curves to other molecular properties.

(*d*) *Development of Chemico-physical Techniques.*—An important part of the programme is the improvement of experimental techniques and the development of new types of apparatus; a new technique often provides data which enable a theoretical advance to be made.

(i) *Electron Microscopy.*—The technique of ultra-thin sectioning has been greatly improved and has been applied to further examination of ferritin crystals. During these investigations the effect of cross-linking the plastics used as embedding agents was studied.

(ii) *X-ray Diffraction.*—Modifications have been made to the high-power gyrating anode X-ray generator and it is now being reassembled.

(iii) *Electron Diffraction.*—A new electron diffraction camera has been constructed and is now being tested. In this instrument it is possible to take an electron micrograph of the sample whose diffraction pattern is being recorded. The development of improved methods of measuring the intensities of diffracted beams has continued.

(iv) *Computers.*—The determination of crystal structures by X-ray or electron diffraction methods inevitably involves an enormous amount of computation. The design of suitable analogue computers has been undertaken and construction of an image-seeking computer has commenced. The designs of a structure factor computer and a Fourier synthesizer are well advanced.

(v) *Spectroscopy.*—The technique of applying atomic absorption spectra to spectrochemical analysis has been further developed and construction of an atomic absorption spectrophotometer has been completed. An English firm will manufacture similar equipment under licence. It is expected that this new technique, which has been developed entirely by the Division, will have a wide application.

The incorporation of the multiple-pass principle in double-beam spectrophotometers is proceeding and an ozone spectrophotometer based on the double-pass principle has been designed.

(vi) *Mass Spectroscopy.*—A demountable type of mass spectrometer has been designed and constructed. The instrument is designed to produce large ion currents at moderate resolving power; it is intended for application to free radical studies and also as the prototype of an inexpensive mass spectrometer which will be suitable for routine process control in industry and for stable isotope assay.

The analysis of gas samples in the mass spectrometer requires a pressure gauge for the range 10-10,000 μ Hg. A suitable gauge which employs a glass spiral as the pressure element has been designed and tested. The gauge has the same sensitivity for all gases and can withstand the sudden application of atmospheric pressure.

(*e*) *Service Work.*—There is a heavy demand for service work requiring the application of the Division's specialized techniques. A selection of the more important problems submitted by industry, universities, medical institutions, and other parts of the Organization is given below.

(i) *Electron Microscopy.*—Investigation of chloroplast and tonoplast structure; a study of the interaction between kaolinite and halloysite in suspension; investigation of lysogenic strain of *Streptococcus lactis;* examination of sheaths from the larvae of a trichostrongyle parasite of sheep; examination of the peritrophic membranes of certain insect pests; investigation of a membrane from the pulp cavity of teeth; examination of virus affecting Australian plants; examination of fowl sperm; studies of the pasture pest *Pterolecera;* various investigations related to the extraction of uranium from certain Australian ores.

(ii) *Electron Diffraction.*—Identification of a blemish on stainless steel; a study of the orientation relationships in the α-γ transformation in iron.

(iii) *X-ray Diffraction.*—Examination of iron oxides used in gas purification; characterization of the phases in soap produced by different milling processes; examination of fowl sperm tails; study of the structure of cryptopleurine.

(iv) *Spectroscopy.* — Investigation of ultraviolet and infra-red spectra of alkaloids; study of deterioration of paint films by reflection spectroscopy and establishment of colour standards; spectrographic assay of antimony ores; development of a colorimetric method for the assay of antimony ores; spectrographic analysis of various alloy and mineral samples; infra-red spectroscopic study of the molecular structure of substituted sulphonamides; infra-red study of hydrogen-bonding in crystals of long-chain aliphatic compounds; further infra-red studies of porphyrin derivatives.

(v) *Mass Spectroscopy.*—Analysis of isotope ratios in deuterated naphthalenes; analysis of products of photolysis of acetaldehyde; detection of ethane in a sample of ethylene; measurement of the oxygen isotope ratio in samples of fossils; identification of an impurity in a sample of commercial carbon dioxide.

(*f*) *Instrument Laboratory.*—In addition to service work and small jobs of all kinds, the Instrument Laboratory has completed the following major items during the year: a small mass spectrometer; an electron microdiffraction camera, which includes provision for electron-microscopic observation of the specimen; an atomic absorption spectrophotometer; various regulated power supplies; temperature controllers; hollow-cathode discharge tubes; distillation columns; gas analysis apparatus. There has been an increasing demand from other laboratories for the polishing of prisms of alkali halides.

A new design of screw-thread correcting lathe has been forwarded to the Department of Supply and advice has been given on the cutting of large gears.

7. ORGANIC CHEMISTRY.

(Division of Industrial Chemistry.)

The research programme is concerned with the following main topics: the investigation of waxes, with particular reference to the chemistry and utilization of wool wax and sugar-cane wax; the examination of Australian plants for alkaloids of possible pharmaceutical value and for substances toxic to live-stock; the investigation of oils and fats, particularly the search for potentially valuable seed oils from native sources; synthetic resins and plastics.

(*a*) *Wool Wax.*—Work has been continued on the identification and estimation of the constituents of wool wax, and on their conversion to commercially useful products. This work is described in Chapter XVI., Section 4.

(*b*) *Sugar-cane Wax.*—It has been previously shown that sugar-cane wax, after freeing from mineral matter, may be bleached by chromic acid to give a light-coloured acidic wax. To test the general applicability of this method, hitherto used mainly on wax from a single mill, a survey has been made of waxes obtained by extracting muds from 28 mills. The softness of most of the bleached waxes and their great variability make it clear that it will usually be necessary first to remove the softer components by vacuum distillation in order to obtain a hard wax. However, there seem to be conditions under which crude waxes of increased hardness and melting point can be obtained; some samples have been particularly good in this respect. Work is in progress to discover what these conditions are.

Seasonal variations, in both the crude wax content and the properties of the extracted wax, have been studied in samples of fresh filter muds received at intervals from selected mills throughout the 1953 crushing season. Experiments have also been made in regard to the variation in properties of the hard wax fraction obtained by acetone refining from fresh and old muds. A small amount of acetone-refined hard wax has been bleached, and tests on the product show that it closely resembles the bleached sugar-cane wax now manufactured in the United States.

Work on chemical modification of the bleached wax along the lines described in the last Report is being continued. An application for a patent covering various derivatives of the bleached wax has been lodged.

(*c*) *Carnauba Wax.*—With a view to developing techniques for studying the chemistry of waxes, and as a guide to the investigation of the more complex sugar-cane wax and wool wax, work has been done on the isolation of the constituents of carnauba wax. This work is also of interest in view of the highly desirable physical properties of carnauba wax, and the light its composition may shed on the requirements of substitute waxes. Seven straight-chain aliphatic acids (C_{18} to C_{30}) and four primary diols (C_{22} to C_{28}) have been isolated and identified, and work is nearing completion on the identification of five hydroxy-acids.

(*d*) *Plant Alkaloids and Stock Poisons.*—The emphasis in this work has been placed on stock poisons. Work on the pyrrolizidine bases which are responsible for liver damage in stock continues, and structural studies of the three minor bases of *Heliotropium europaeum* have been completed. Detailed alkaloid assays are being carried out on samples of *H. europaeum* from representative areas of Victoria and New South Wales, to provide a preliminary survey of alkaloid variability for the Division of Animal Health and Production. These assays will conclude the heliotrope investigation. Five alkaloids, one of which contains chlorine, have been isolated from *Senecio jacobaea* and structural investigations of these bases are in progress. Other plants from which pyrrolizidine alkaloids have been isolated are *Erechtites quadridentata, Crotolaria mitchellii,* and *Echium plantagineum* (Paterson's curse).

The investigation of *Lupinus pilosus* (common blue lupin) has been completed. Three alkaloids, together with the *N*-oxide of one of them, have been isolated from the seeds, and three more from the tops of the plants. Biological testing of the major components is in progress in the Division of Animal Health and Production.

The investigation of "Phalaris staggers" in collaboration with the Division of Biochemistry and General Nutrition is proceeding. An extract of toxic grass has been prepared; in tests, it failed to produce the symptoms of staggers, although some deaths occurred. An attempt is being made to isolate the substance responsible for curariform activity detected in *Phalaris* grass grown in Tooradin, Victoria. Search for the toxic principles of *Atalaya hemiglauca, Indigofera endecaphylla,* and *Romulea bulbicodium* has been made, but so far without result.

Work on *Atherosperma moschatum* was concluded in 1953, resulting in the isolation by counter-current distribution of seven alkaloids, six of which occur in very small amounts. The major constituent was identified as berbamine and this tree is probably the world's best source of the alkaloid. Since the quaternary salts of berbamine are of possible interest as curarizing agents, a commercial process is being devised for its extraction. Work on the alkaloids of *Kopsia longiflora* has been continued, and two additional alkaloids isolated. All four alkaloids so far detected are ester types and biological tests are in progress.

Structural studies on the unique vesicant alkaloid cryptopleurine have been greatly assisted by the determination of the structure of *iso*cryptopleurine methiodide, using X-ray crystallographic methods. *Iso*cryptopleurine has a fused phenanthrene-quinolizidine nucleus, but the presence of the same nucleus in cryptopleurine itself is uncertain. Progress has also been made with a projected synthesis of cryptopleurine. Cryptopleurine has been found to exhibit mutagenic activity towards *Drosophila,* but it also induces a high degree of sterility. *Cryptocarya pleurosperma* leaves have yielded no cryptopleurine, although other bases are present.

(*e*) *Fats and Oils.*—(i) *Chemistry of Tallow Constituents.*—Further work has been done on the problem of increasing the unsaturation of olefinic substances, with a view to converting low grade non-drying oils, such as commercial olein, into more valuable materials with drying properties. The procedure of substituting a chlorine atom at a position adjacent to an existing double bond, followed by removal of hydrogen chloride to form a new double bond, has been examined with a variety of simple model olefins, but the re-agents so far examined for introducing the chlorine have not proved generally applicable.

Some work has been done on the preparation of mixed hydroxystearic acids in quantity from sulphated oleic acid. This mixture of hydroxy-acids is potentially available in quantity, and preliminary tests are being made of their value in wax preparations and in lubricants.

(ii) *Investigation of Potential Seed Oil Resources.*—In the past few years much attention has been given in India to the seed fat (Kamala oil) from *Mallotus philippinensis*, a small tree of the Euphorbiaceae which seeds prolifically. This seed fat shows great resemblance to tung oil, and dries to films which are very resistant to water, organic solvents, acids, and alkalis. The composition of Kamala oil is not fully known, but its principal component acid has been shown to be a hydroxyeleostearic acid, which suggests that the oil will differ sufficiently from tung oil to have slightly divergent fields of use. The plant is widely distributed in Queensland, and a preliminary examination of the oil is in progress.

The seed fats of the sweet and bitter quandongs (*Santalum acuminatus* and *S. murrayana*) have been found to be rich in acetylenic acid, octadecenynoic acid, which is identical with the ximenynic acid recently isolated in South Africa from *Ximenia americana*, and possibly also identical with the santalleic acid obtained from the seed fat of Indian sandalwood (*S. album*). The acid may prove to be a characteristic component of the seed fats of the genus *Santalum*.

(*f*) *Synthetic Resins and Plastics.*—(i) *Kinetics of the Phenol-formaldehyde Reaction.*—The study of the phenol-formaldehyde reaction using 2,6-xylenol with excess alkali has shown the reaction to be complex with regard to the concentration of xylenol, formaldehyde, and hydroxyl ion. A mechanism giving approximate correspondence with the results has been proposed. The work has now been concluded.

The conversion of formaldhyde in alkaline solution to methanol and formate, known as the Cannizzaro reaction, had of necessity to be studied during the above investigation. Despite much previous work the mechanism of this reaction had never been adequately clarified; now for the first time it has been clearly shown to be a combination of a third and a fourth order reaction.

Another consequence of this work has been the preparation of a number of phenols and their derivatives, either not previously known or obtained only by troublesome methods. Prehnitinol has been satisfactorily prepared by the action of hydrocyanic acid on 2,3,5-trimethylphenol (now a commercial product) with subsequent reduction. Catalytic hydrogenolysis of phenol alcohols using copper-chromite has been extended from the one example hitherto recorded to a number of substituted phenol alcohols.

(ii) *Tigaso Oil.*—The chemical investigation of this exudate from the New Guinea tree *Camphospermum brevipetiolatum* has been continued using adsorption techniques to separate the components. Its possibilities in resin formulations are also being examined because of its similarity to the liquid secretion obtained from the shell of the cashew nut, which is greatly in demand for certain types of phenolic resins noted for their chemical resistance and rubbery properties.

Results so far indicate that, apart from a phenol which may be identical with that reported in work done some twenty years ago at the University of Queensland, there are components which readily break down to stearic acid and methyl heptadecyl ketone.

(iii) *Cyanide Polymers.*—Hydrocyanic acid and some cyanides can give rise to polymeric materials that have not been fully characterized. The preparation of one such polymer, "paracyanogen", by the electrolysis of potassium cyanide solution was described in 1892, but the method does not appear to have been examined since. Work has now commenced on this, for the method appears simple, and the starting compound—one of the simplest organic substances capable of polymerization — readily accessible. Material so far prepared is not paracyanogen, but a complex acid of unknown structure, generally known as azulmic acid.

(*g*) *Microanalytical Laboratory.*—The services of the Microanalytical Laboratory are being used to an increasing extent by organic chemists. All standard microanalytical determinations can be undertaken, as well as some special ones for individual research projects, and the delay between receipt of a sample and the submission of the results is now very short, even for the more complicated determinations. During the year some 4,600 separate analyses were carried out—an increase of 1,000 over the previous year; approximately 40 per cent. of these were for universities, and 30 per cent. each for governmental laboratories and industry.

(*h*) *Composition Tables.*—A project has been commenced for the compilation and publication of tables of a new type connecting the composition of organic compounds with their molecular formulae. All previous composition tables merely enabled the composition corresponding to a known formula to be obtained, with a saving of a small arithmetical calculation. The present tables are arranged in the opposite way, and enable the chemist who has found the elementary composition of an unknown compound to obtain all the molecular formulae which are consistent with his analysis by simple inspection, thus eliminating what was previously a rather laborious process of trial and error, with the possibility of missing the correct formula. The use of the digital computer, and accessory equipment belonging to the Division of Radiophysics, has made it possible to construct such tables without the vast amount of calculation otherwise necessary. Further, the various mechanical checks provided by these machines preclude the possibility of chance error. The tables for C, H and C,H, and O (with C, H, O, S) have been completed and are now in the press. It is proposed to proceed with tables for use with compounds containing nitrogen. The tables should be of permanent value and not subject to revision.

8. CHEMICAL ENGINEERING.

(Division of Industrial Chemistry.)

Most of the resources have been directed to the study of the techniques and reactions of importance in the gasification of low-rank coals. The research programme is broadly determined by the Consultative Committee on Brown Coal Research and Development, as a result of which this work, and that of the Gas and Fuel Corporation of Victoria on pressure gasification, have been closely co-ordinated. The Committee consists of representatives of the State Electricity Commission of Victoria, the Gas and Fuel Corporation of Victoria, and the Organization.

Results are now being obtained on several aspects of this research, following the completion of nearly all the work of constructing and equipping laboratories, recruiting and training staff, and designing and constructing pilot plants and experimental apparatus. Two research officers who have completed traineeships overseas returned during the year and four others will return next year.

In addition to fuel research, the Division has investigated the roasting of alunite in a fluidized state and the sulphate roasting of copper concentrates.

Through its Process Laboratory the Division provides a service to industry and to other parts of the Organization by its use of a wide range of equipment to test processes on a pilot scale.

In addition to the work described below, a number of fundamental studies having application in chemical engineering are described in Section 5 of this Chapter.

(*a*) *Coal Utilization.*—Both fundamental and pplied studies of the gasification of coal have been ontinued. These are described in Chapter XX., ection 7.

(*b*) *Alunite Investigations.*—A preliminary investi- ation of the roasting of Western Australian alunite the fluidized state has been concluded. The results ave shown that this method of roasting gives a gnificant improvement in the yield of soluble potash ver that obtained by roasting in a rotary kiln. The ptimum conditions for batchwise roasting in a uidized bed have been determined, and an estimate as been made of the yield to be expected when ontinuous roasting is practised.

Preliminary designs for a multi-bed industrial-scale oaster have been prepared. Further work on this ropect is dependent on a new evaluation of this Vestern Australian industry based on the improved erformance of the new roasting process.

(*c*) *Roasting of Copper Concentrates.* — In ccordance with a co-operative agreement between the rganization and two major mining companies, Mount Iorgan Ltd. and Mount Lyell Mining and Railway o. Ltd., a large pilot plant has been erected to nvestigate the sulphate roasting of copper concentrates a fluidized bed reactor. This is the first stage of new process for recovery of copper and precious netals from sulphide ores. This process consists in ontrolled roasting of the concentrates to convert the opper into a form soluble in dilute sulphuric acid, eaching of the calcines, and electrodeposition of the opper from the solution. The precious metals which emain in the residues after leaching may be recovered y cyanidation.

The pilot plant, which has a capacity of three tons er day, was completed and put into operation in anuary, with Mount Lyell concentrates as the feed. he results so far obtained have been most encouraging.

(*d*) *Process Equipment Laboratory.*—During the ear the Process Equipment Laboratory provided acilities for the Division, for other Divisions, and or a number of industrial firms. Six investigations ere carried to a pilot-plant scale, some 20 tests ere made on special items of process equipment, and 2 extractions of natural materials were made as a reliminary to laboratory investigations. In addition number of technical inquiries were handled and ome time was given to research on the desalting of ore water by solar distillation.

The range of process equipment was increased by he installation of a lead-lined reaction vessel, a ressure leaf filter, a grass-drying cabinet, and a acuum evaporator of the falling film type.

9. RADIOACTIVE TRACER MATERIALS.

(Tracer Elements Investigations.)

This Unit, which is housed in the Chemistry Depart- nent of the University of Melbourne, is developing a ange of radioactive tracer techniques applicable to hemical and biological studies. The Unit arranges for he supply of radioactive and stable isotopes to the other Divisions and Sections. If a labelled compound is not eadily available overseas, the Unit may undertake to ynthesize it.

The Unit has continued to advise on tracer methods enerally. During the year the facilities of the Unit ave been made available to several guest workers.

The research work of the Unit consists of three nain items:

(i) A study of the reaction kinetics of molecules ontaining carbon-14. In many reactions "isotope ffects" may be observed, owing to slight differences n the rates of reaction of ^{14}C and ^{12}C. This phenomenon is important in the quantitative determination of ^{14}C and also gives information on mechanisms of reaction. At present certain intramolecular rearrangements are being studied.

(ii) The extension of analytical methods using radioisotopes. Variations of the "isotope dilution" method of analysis are being studied. In conjunction with the Chemistry Department, University of Melbourne, radioactivation is being applied to the analysis of traces of gold.

(iii) Study of organic radiation chemistry. A start has been made on the application of tracer methods to a study of the effects of ionizing radiation on organic compounds.

(*a*) *Collaborative Work.*—The Unit has assisted the Physiological Department of the University of Melbourne in a study of the physiology of teeth using ^{32}P, and Monsanto Chemicals (Aust.) Ltd. in an industrial application of radioisotopes. Collaboration with the Division of Animal Health and Production on the fate of ^{35}S-labelled sulphate in sheep was commenced.

(*b*) *Syntheses.*—More techniques for the synthesis of compounds labelled with radioactive isotopes are being developed. Syntheses undertaken for other Australian workers are restricted to compounds with high specific activities which are not available elsewhere. The Kolbe reaction has been used to synthesize ^{14}C-labelled salicylic and 5-chlorosalicylic acids. Other ^{14}C-labelled compounds prepared include saligenin, *o*-cresol, *o*-cresoxyacetic acid, sodium acetate, and tyrosine.

(*c*) *Radioactive Assay Methods.*—Gas counting of carbon dioxide containing ^{14}C is being developed. This method is valuable for the assay of weak samples such as those often obtained in biological tracer work, and can be used also for assaying other soft β-emitters such as tritium and ^{35}S. Facilities for scintillation counting and autoradiography are also being established.

XIX. MINERAGRAPHY AND ORE-DRESSING.

1. GENERAL.

The importance of investigations for the development of the mining industry and the utilization of Australia's mineral resources is fully recognized by the Organization.

Mineragraphic work to provide information on the mineral composition of ores has been in progress in Melbourne since 1927. The techniques used are highly specialized and require considerable experience, so that it is only rarely that they can be applied by the staffs of operating mines. The current work of the Mineragraphic Investigations Unit is described in Section 2 of this Chapter.

The Ore-dressing Laboratories operated in Melbourne in collaboration with the University Department of Mining, and in Kalgoorlie in co-operation with the School of Mines, investigate the composition of ores and provide advice on suitable methods for their full-scale treatment. This work is reported in Sections 3 and 4 of this Chapter.

Work on the utilization of minerals is carried out by the Division of Industrial Chemistry (*see* Chapter XVIII., Section 2).

2. MINERAGRAPHIC INVESTIGATIONS.

(Mineragraphic Investigations Unit.)

Forty-four investigations have been made on the mineral associations of rock, drill cores, and mill products submitted by mining companies. A number of these related to the search for new mineral deposits. Five were concerned with the experimental treatment of ores in the Ore-dressing Laboratories.

Dr. F. L. Stillwell retired at the end of June, 1953, and was succeeded as Officer-in-Charge by Dr. A. B. Edwards. Dr. Stillwell continued to work in the laboratories throughout the year on a study of the mineralogy of the Broken Hill lodes, which was undertaken by the Unit in conjunction with the Broken Hill Geological Research Committee.

Examination of uranium ore from Rum Jungle, Northern Territory, revealed the occurrence of cobalt in the ore as a mineral of the linnaeite-carrolite series, and of bismuth as an association of native bismuth, aikenite, and wittichenite. Radioactive ores from Broken Hill, New South Wales; Mount Isa, Queensland; and the Adelaide River, Northern Territory; were also investigated.

A combination of polished section examination and X-ray study of manganese ores at Tamworth, New South Wales, and at Mary Valley and Amamoor, Queensland, brought to light new occurrences of the relatively rare manganese minerals tephroite, alabandite, piedmontite, braunite, and hausmannite. The very rare silver selenide naumannite was identified in ore from the Duchess mine, Queensland.

A beach sand from near Samarai, Papua, was found to contain upwards of 40 per cent. of chromite, and an ilmenite concentrate from Stradbroke Island, Queensland, was found to contain about 10 per cent. of ferriferous rutile.

The complex silver-lead ores of Yerranderie, New South Wales, revealed interesting minerals and textures associated with secondary silver enrichment, and a study of the ore from the Sardine Tin Mine, Queensland, indicated the behaviour on weathering of the relatively uncommon copper-tin sulphide mineral, stannite.

Mineral associations were determined in primary copper ore from the Peko mine, Northern Territory, zinc-lead ore from Mount Werong, New South Wales, antimony ore from the Magword mine, New South Wales, the King Island (Tasmania) scheelite concentrates, and the Storey's Creek (Tasmania) wolfram concentrates.

Exceptionally high silver values in otherwise poorly mineralized ore from the New Broken Hill Consolidated mine proved to be due to the occurrence of primary native silver; and the replacement of unmetamorphosed epidiorite dykes in the old Proprietary mine at Broken Hill by lead-zinc ore and manganiferous garnet established that the Broken Hill mineralization post-dated the regional metamorphism of the area.

A survey of the selenium content of the sulphide minerals in a wide range of Australian ores has revealed that in most hydrothermal ores the pyrite has a sulphur:selenium ratio of the order of 10,000, whereas sedimentary pyrite occurrences have a ratio of the order of 100,000. This has been applied to determine that the mineralization associated with particular persistent stratigraphic horizons in the Nairne district, South Australia, and in the Mount Isa district, Queensland, are of hydrothermal origin. Australian ores in general have a low selenium content, although some ores in the Duchess area, Queensland, and the Bathurst district, New South Wales, are relatively rich. Copper concentrates are the chief source of recoverable selenium.

The investigations have been facilitated by contributions from a number of mining companies through the Australasian Institute of Mining and Metallurgy, and at the Institute's suggestion most of these companies have substantially increased their contributions. The University of Melbourne has co-operated in providing laboratory accommodation.

3. Ore-dressing Investigations.

(Melbourne Laboratory.)

Work done at Melbourne, in the Mining Department of the University, is recorded in 30 reports (Nos 453-482 inclusive). These refer to treatment method for ores of gold, silver, platinum, copper, lead, zinc tin, tungsten, cobalt, tantalum, and antimony, and t the concentration of diamondiferous gravels, dun lime-sands, and beach sands containing valuable heav minerals.

Effective separation of alluvial diamonds from a ra material containing much zircon was achieved b addition of small quantities of dry finely groun common salt, which increased the surface conductivit of the zircon.

Further work was done on the magnetic separatio of chromite from ilmenite. By magnetic separatio after heat treatment a product assaying less than 0. per cent. Cr_2O_3 and containing over 80 per cent. of th original titanium has been obtained. The magneti susceptibility of ilmenite is markedly altered by heatin to temperatures between 400 and 1,000° C. Oxygen nitrogen, and hydrogen atmospheres have been used with oxygen there is a weight increase and wit hydrogen a decrease, but in both atmospheres th magnetic susceptibility increases, although not to th same extent. X-ray examination indicates that change in crystal structure also occur. Work continues in a attempt to correlate these phenomena, with the objec of determining the best heat treatment conditions fo effective magnetic separation.

A cassiterite-cuprite ore from the Northern Territory provided striking evidence that, despite high grade an ore may have little present value owing to intimat association between valuable minerals and gangu and to the occurrence of a mineral (cuprite in thi ore) which cannot be concentrated by method applicable on a small scale in an isolated locality This is a type of ore which would warrant much mor extensive investigation if ore reserves were large.

Investigations of tungsten ores from southern Ne South Wales illustrate the importance of separat examination of adjacent ore bodies. In testing th deeper and larger of two superimposed ore bodies 10 feet apart, the optimum recovery of tungsten afte exhausting the possibilities of gravity concentratio was 25 per cent. lower than from the shallower or body.

A copper-silver ore from the Northern Territor consisting almost entirely of intimately associate sulphide minerals, including pyrrhotite, provide another example of the beneficial effect of pre-aeratio before flotation. Better recovery of both metals in higher grade concentrate was obtained. Best result were obtained in a lime circuit at a pH above 11.

Attempts to extract gold and silver by cyanidatio from a Queensland lead carbonate concentrate wer successful. Fine grinding was necessary. The pul was buffered at about pH 9 and no free alkalinit could be maintained in the solution. Increased lim additions improved recovery of silver but not of gold

A difficult sampling problem was encountered i examining a low grade gold ore from New Sout Wales. It was shown that while most of the gol was fine, erratic results were due to a small proportio of relatively coarse gold.

An extensive but not exhaustive investigation wa carried out on several samples of a rich, partly oxidize copper-gold ore from the Northern Territory. Th work done included an investigation of flotation concentration with supplementary gravity concentratio and acid leaching. Data were accumulated whic would serve as a guide to the design of suitable treatment plant.

Interest is maintained in the possibility of recovering cobalt both from copper ores and from manganese ores. The latter frequently contain nickel as well but generally it is not possible to make a cobalt concentrate because of the extremely intimate association of the metals present. Interesting technical and economic problems are involved in the recovery of cobalt by leaching methods. From one ore 84 per cent. of the cobalt was extracted by leaching with aqueous sulphur dioxide, but 75 per cent. of the more abundant manganese also dissolved. Reduction of the ore by hydrogen at 950° C., followed by leaching with ammonia and ammonium carbonate, extracted 64 per cent. of the cobalt in a relatively pure solution. Further investigation of the latter process appears to be justified.

4. Ore-dressing Investigations.

(Kalgoorlie Laboratory.)

Up to December, 1953, the results of all work were given in consecutively numbered reports, which had quite a wide distribution. Many of these reports contained the results of assays, of analyses, or similar information recording only measurements, and were of little interest to anyone except the sender of the sample. Since January the Laboratory has issued reports giving the results of metallurgical investigations, and certificates giving assays, analyses, and similar information. The Reports have been distributed as in the past, but certificates have been sent only to the sender of sample(s). This policy has been found quite satisfactory and will be continued.

During the year 44 reports were issued. Of these ten referred to gold ores, four to ores of other metals, and ten to non-metallics, and the remaining twenty recorded assays or analyses. Since January, seventeen certificates have been issued. Brief reference will be made in the following paragraphs to the more important investigations, particularly those of general interest.

Work done on a bentonite clay from Marchagee, Western Australia, showed that when this clay was conditioned with 3 per cent. sodium carbonate it would produce a drilling mud equivalent in quality to that produced by imported bentonite. Marchagee bentonite is now being used at Collie, Western Australia.

A concentrate assaying 50 per cent. sulphur with a recovery of 94 per cent. of the sulphur in the ore was obtained from a pyrite ore from Norseman, Western Australia, by grinding to minus 100 mesh and by flotation under favourable conditions.

At the request of the Western Australian Department of Industrial Development beneficiation tests were made on lime-sands containing 81 per cent. calcium carbonate and about 10 per cent. silica. Table flotation yielded a concentrate containing 90.2 per cent. calcium carbonate and 0.38 per cent. silica. Approximately 99 per cent. of the calcium carbonate was recovered. This work is described in a paper on table flotation by C. H. S. Meharry read at the 1954 ordinary meeting of the Australasian Institute of Mining and Metallurgy.

An investigation showed that the method of treatment of the gold ore at Sunshine Reward gold mine, near Marvel Loch, Western Australia, could be changed from the present stamp battery crushing and leaching practice to fine grinding and continuous agitation cyanidation. Information for plant design was given.

Good grade graphite concentrates were obtained from ore samples from Munglinup, Western Australia, by flotation.

Test work on some columbite gravel from Pilgangoora, Western Australia, showed that this contained 12 lb./cu. yd. of rough columbite concentrate, and enabled advice to be given about plant design. Arrangements have been made for the Senior Research Metallurgist to visit the plant late in June and to assist in overcoming any troubles associated with initial operation.

Work on carefully taken samples from the old Menzies Consolidated tailings dump at Yunndaga, Western Australia, showed that different portions of the dump yielded from 0.38 to 1.10 dwt. gold per ton. Some portions of the dump were, however, not suitable for percolation cyanidation because of the very slow leaching rate.

XX. FUEL.

1. General.

The Organization's fuel research programme is at present mainly confined to coal. There is insufficient knowledge concerning the properties and characteristics of Australian coals and an urgent need for this knowledge exists so that the best and fullest use may be made of the available resources.

The Organization's main centre for investigations on fuels is the Coal Research Section, located at North Ryde, New South Wales. This Section was established to undertake a fundamental and comprehensive study of the physical and chemical characteristics of Australian coals. The work of the Section is reported in Sections 2-5 of this Chapter.

The Division of Industrial Chemistry undertakes work on the engineering aspects of gasification of low-rank coals, and this is reported in Section 7 of this Chapter.

Co-operative investigations on the fossil pollens in brown coal are undertaken in the Botany School of the University of Melbourne, and are reported in Section 6 of this Chapter.

The Organization's Central Experimental Workshops at Maribyrnong, Victoria, are studying the design and construction of solar water heaters for domestic and industrial applications, and this work is reported in Section 8 of this Chapter.

Coal Research Section.—The main object of this Section's investigations is to make available accurate and systematic data on indigenous coals so that: (i) their coking, gas-making, and burning properties may be known and their behaviour on carbonization and combustion predicted with some degree of accuracy; (ii) an evaluation may be made of the beneficiation likely to result from coal cleaning and preparation; (iii) various methods of thermal and direct chemical utilization may be assessed.

The work of the Section, however, is concerned not only with long-term problems of the quality of coal on a national basis, but also directly with current and future problems of coal utilization.

Considerable progress has been made towards establishing the facilities required for programmes already commenced, and the activities of the Section continue to expand as staff is trained and equipment obtained.

Buildings have been completed and pilot-scale carbonization plant, combustion furnaces, and equipment for testing the mechanical properties of coal put into operation. Large-scale plant for investigating washability characteristics of coal and methods of cleaning fine coal has been installed and grateful acknowledgment is made to the Fuel Research Institute of South Africa for much valuable information supplied in connexion with the installation. Work has also started on determination of the plastic behaviour of coals during carbonization.

The examination of bores drilled by the Joint Coal Board has continued, and has formed a major proportion of the Section's coal survey activities during the past year. Work also has been carried out in collaboration with the Aeronautical Research Laboratories of the Department of Supply on the problem of ash deposition on turbine blades when burning pulverized Victorian brown coal. Over 60 location reports of seams examined were prepared during the year. A large number of technical inquiries were dealt with, over 40 of which were of major importance.

In his capacity as Australian member of the Commonwealth Committee on Fuel Research, the Officer-in-Charge continues to act as co-ordinator of reviews of fuel research carried out by official fuel research centres throughout the British Commonwealth and dealing with: (*a*) physical testing of coal and petrographic investigations, and (*b*) brown and sub-bituminous coals. Liaison with Australian and overseas standards authorities continues in work on the classification of coal and the standardization of testing methods.

2. EXAMINATION OF COAL SEAMS.

(Coal Research Section.)

Survey work for this year has been on seams in both the Upper and Lower Coal Measures in the Northern Coalfield of New South Wales.

The survey of the Greta (Lower Coal) Measures in the Maitland, Cessnock, and Muswellbrook areas is continuing. The examination and analysis of eight seam profiles of the Main Greta and seven from the Homeville seams have been completed during the year. Eight samples have been taken at collieries working the Borehole seam at the base of the Newcastle series.

Samples of presumed Greta coals have been obtained from the three major producing seams in the Muswellbrook open cut and from a seam outcropping in the extreme north of the New South Wales Northern Coalfield in the vicinity of Ashford. The latter was required in connexion with a proposal to build a new power station near Ashford.

The coal at Ashford proved to be a high-rank bituminous, medium volatile type, low in ash content, sulphur and phosphorus. Considering its proximity to the surface, coking properties were well developed and the coal could be utilized for the manufacture of metallurgical coke. Ease of grinding and an exceptionally low abrasion index, combined with high calorific value and refractory ash, indicated that the coal would also be very suitable for use as pulverized fuel for steam generation.

A total of 23 borehole cores have been examined on behalf of the Joint Coal Board from the Muswellbrook-Singleton, Newcastle, and Mount Murray localities. Four of these boreholes were shallow bores in the Liddell district, proving the Liddell, Barrett, and Pikes Gully seams in the Tomago series of the Upper Coal Measures. Thirteen bores resulted from a concentrated drilling programme in the Balmoral area, south of Muswellbrook; individual coal plies from a 20-30 ft. seam penetrated in this series were found to have apparent specific gravities varying between 1.22 and 1.25 and ash contents from 4 to 7 per cent. These are exceptionally low figures for Australian coals.

Other boreholes examined were drilled in the neighbourhood of Newcastle (Northern Coalfield) and Mount Murray (Southern Coalfield).

The installation of equipment for large-scale detailed float and sink testing, to determine the washability characteristics of all sizes of coal on run-of-mine products, is nearing completion.

3. COAL CONSTITUTION.

(Coal Research Section.)

(*a*) *Petrography.*—Petrographical studies form an important part of the investigations into the chemical, physical, and mechanical properties of coal, and of its behaviour under various conditions such as storage, grinding, carbonizing, &c.

The petrographical structure of a number of New South Wales coal seams, including the Bulli, Wongawilli, Main Greta, and Homeville seams, has been studied in thin sections using transmitted light, and in polished sections using incident light.

Investigations of the possibility of using the distribution of certain microspores for the purpose of intercorrelating coal basins and individual seams is being continued. Studies of the spore distribution in seams penetrated by the bore cores and trial shafts mentioned in Section 2 of this Chapter have been carried out and reports have been completed on spore distributions in the South Wallarah area (Northern Coalfield, New South Wales), and in the seams traversed by Dobb's Drift (Western Coalfield, New South Wales). Investigations are also proceeding into the use of spores for seam correlation in the Balmoral area.

Special investigations include a study of the occurrence of sulphide minerals in New South Wales coal seams and a comprehensive examination is in progress of the opaque macerals present in Australian Permian coals. Unusual occurrences of kaolinite petrifaction in the Bulli and Tongarra seams have been observed and reported.

(*b*) *Physical and Chemical Properties.*—(i) *X-ray Diffraction Studies.*—These are of fundamental importance in the investigation of the chemical and physical structure of coals. For this purpose a low- and medium-angle Geiger counter X-ray spectrometer has been designed and is being constructed. This will be used initially to study the molecular and colloidal structure of coals and cokes.

(ii) *Heat of Immersion.*—An examination has been made of the validity of estimating internal surface areas from measurements of heats of immersion in various liquids, and this has led to the view that heat of "wetting" is probably a measure of an interaction of the wetting liquid with polar groupings in the coal substance rather than a measure of the internal surface area. The heats of immersion of coals in methanol have been measured on a large number of samples and the results are being analysed.

(iii) *Solubility in Ethylenediamine.*—The solubility of New South Wales coals in anhydrous ethylenediamine has been found to be similar to that of British coals of the same rank. It has been found that the solubility of the coals varies with the number of acidic groupings which are detectable by potentiometric titration in suspension in ethylenediamine.

(iv) *Refractive and Absorption Indices.*—An apparatus has been constructed for determining the refractive and absorption indices of coals by measuring the angle of maximum polarization of reflected light.

Variations in refractive index at different levels of a coal seam have been observed and it is hoped to correlate these with petrographic constituents and mineral content. The phenomena of anisotropy exhibited by coals in varying degrees is also being studied.

(v) *Equilibrium Moisture Content.*—A proposal put forward by the Economic Commission in Europe for an international classification of coal based on calorific value expressed on a standard moisture, ash-free basis has called for the investigation of a method for determining the "equilibrium moisture content" or oisture holding capacity" of Australian coals n exposed and equilibrated under strictly prescribed ditions of humidity and temperature.

vi) *Inorganic Constituents.* — The nature and uence of the mineral matter associated with coal of profound significance in the combustion, gasifica- , and carbonization of coal, and are being given ial attention.

sh fusion and clinkering characteristics are being estigated using the pot furnace techniques.

n investigation of the approximate ash analysis and usefulness has been carried out. For British coals as been suggested that the tendency of a coal ash form clinker may be predicted from estimations he water-soluble, acid-soluble, and insoluble fractions coal ash, but the data obtained for ash from Aus- ian coals do not appear to correlate with clinkering perties nor with the fusion point of the ash.

he relationship between the mineral matter content coal and the ash resulting from its combustion been the subject of investigation using several niques, including wet chemical analysis, calori- ry, X-ray diffraction, emission spectroscopy, and selective removal of minerals by acid treatment the coal. Such studies should also yield valuable rmation on the possibility of producing ultra-clean from indigenous sources. Chemical analysis and ssion spectroscopy continue to be used for the estima- of trace elements present in all coals examined . boron, germanium, titanium, &c.).

4. COAL UTILIZATION.

(Coal Research Section.)

a) *Combustion Investigations.*—The importance of field of fuel utilization can be gauged by the fact t it absorbs more than half the Australian produc- of deep-mine coal. It is not yet possible to dict the behaviour in use of Australian coals from results of chemical analysis or from abnormalities erved with respect to internationally used methods classification. Because of this, and to establish a re rational basis for utilizing various types of coal. tudy of the ignition and combustion characteristics Australian coals with particular reference to their luation for combustion purposes is being carried . The results of these investigations will sequently be related to performance in large-scale ts.

xperience has shown that no one burnability test be used universally to assess the combustion charac- istics of a fuel under all conditions of use. There- e, equipment has been installed for: carrying out s on the reactivity of coal and coke; determining ignition temperatures of solid fuels, the rate of pagation of ignition in beds, and the inflammability coal dusts in suspension; and investigations on the ning of coal and coke fixed in underfeed and over- d fuel beds.

he technique of operating an experimental furnace measuring the velocity of ignition of coals has been ablished and tests have been carried out on a variety coals.

he pilot-scale combustion furnace for studying the nability of coal fired in underfeed fuel beds has been talled, and preliminary tests on representative coals m three of the main coal producing districts in w South Wales have been completed.

A combustion furnace to simulate overfeed fuel beds almost complete and will be ready for operation ring the forthcoming year.

gnition temperature and inflammability charac- istics of coal dust suspensions and reactivity of coke air are being investigated in all samples of coal and e obtained in the course of the Section's survey rk.

(*b*) *Mechanical Properties.*—The growing demand for pulverized fuel and the increasing attention being paid to the sizing and cleaning of coal emphasize the importance of investigations into size degradation processes. Studies of the mechanical properties of coal include measurements of coal, strength, friability, particle size distribution of the broken material, resistance to breakage by attrition and by impact, grindability, and abrasiveness. Knowledge gained from such studies is essential for good mining practice and the development of efficient coal handling and crushing plant.

The installation of testing equipment for carrying out the above investigations has been completed during the year and a considerable amount of work has been done on coals and associated dirt bands and also on cokes produced in the course of carbonization studies.

Friability (drop shatter test) values for the Greta, Homeville, and Borehole seams vary between 9 and 21 per cent., for the Bulli seam are 13-20 per cent., and for the Lithgow seam 10-11 per cent.

The abrasive index for the Greta, Homeville, and Borehole seams ranges from 30 to 100, for the Lithgow seam is about 85, for the seam at Ashford 16-25, and for Bulli seam 6½-42.

Hardgrove grindability indices for the Greta and Homeville seams are from 35 to 40, compared with 50-55 for the Lithgow seam, 55-62 for the Borehole seam, 75-82 for the Bulli seam, and 80-87 for the Ashford seam.

(*c*) *Carbonization Studies.*—(i) *Carbonizing Properties.*—The carbonizing properties of Australian coals continue to be investigated with a pilot-scale plant similar to that designed jointly by the United States Bureau of Mines and the American Gas Association. During the year test runs have been carried out on samples obtained from the Homeville seam (upper split), Borehole seam, and Lithgow seam. Computations on these and previous test runs continue.

(ii) *Plastic Behaviour of Coals During Carbonization.*—Laboratory measurements of plasticity using the Giesler and Davis plastometers have been made, and the correlation between Gray King carbonization assays and the Audibert-Arnu dilatometer test for Australian coals is being investigated.

(iii) *Fundamental Aspects of Coking.*—Ultimate analysis, infra-red absorption spectra, heat of wetting, surface area, and X-ray diffraction data are being used in combination to examine coals at successive stages of carbonization. The effect of carbon content and the proportion of micrinite on the carbonizing properties are being studied.

(iv) *Carbonizing Conditions.*—Materials and equipment have been obtained for the erection of a pilot-scale slot oven for investigating the carbonizing and blending of coal for production of foundry coke. Working drawings have also been prepared for the installation of a small oven for measuring expansion pressures developed during carbonization.

With the completion of this equipment the Section will have comprehensive facilities available for investigating the influence of carbonizing conditions on coke properties.

5. METHODS OF ANALYSIS.

(Coal Research Section.)

Generally, the methods of analysis used are those specified by the Australian and British standards institutions or by the British Fuel Research Station. Investigation of and comparison with other methods continue.

(*a*) *Direct Determination of Oxygen.*—The direct determination of oxygen has been carried out in coals of a wide range of rank and type and some errors inherent in the difference method have been revealed. It has also been shown that water and oxides of carbon and sulphur derived from pyrolysis of minerals contribute to the value of oxygen content as determined directly.

(*b*) *Tar Analysis.*—Methods of estimation of constituents of tar, e.g., naphthalene, phenanthrene, carbazole, and anthracene, continue to be investigated.

Attempts have been made to develop a rapid method for the estimation of total acids and total bases, and an original method has been developed for the separation of tars into acidic, basic, and neutral fractions by ion exchange chromatography.

(*c*) *Spectroscopy.*—(i) *Emission.*—A method for the rapid quantitative estimation of the major constituents of coal ash is being perfected. Semi-quantitative determination of trace elements is being carried out on coal ashes.

(ii) *Absorption.*—An infra-red spectroscope has been installed and calibrated, preparatory to examining the absorption spectra of coal and tar fractions.

(*d*) *X-ray Diffraction.* — The routine qualitative determination of minerals in coals by X-ray diffraction measurement is being investigated. The predominant minerals of the inorganic matter inherent in New South Wales coal seams so far examined appear to be quartz and kaolinite, occurring in varying proportions. Other minerals such as ferrous oxide, α-titanium sesquioxide, dolomite, calcium carbonate, iron carbonate, and calcium sulphate are recognizable in small quantities.

6. POLLENS IN BROWN COAL.

(Pollen Research Unit.)

The Pollen Research Unit at the Botany School, University of Melbourne, has continued studies on the fossil pollens in brown coals and related Tertiary sediments. Samples from the Birregurra No. 1 Bore, and other deposits have revealed the existence of three distinctive micro-floras of stratigraphic significance in Victoria, and a related Tertiary flora has been discovered in Western Australia.

A study on the composition of brown coal fusain has also been made.

7. UTILIZATION OF LOW-RANK COAL.

(Division of Industrial Chemistry.)

(*a*) *Synthesis Gas.*—For some years, work has been in progress on the production of synthesis gas from brown coal and brown coal chars by steam-oxygen gasification in a fluidized bed reactor. Progress has been limited during this year by the lack of essential information which is being sought in the work described in Section 7(*d*) of this Chapter.

(*b*) *Pressure Gasification.*—Despite the successful development of the Lurgi pressure gasification process, very little is known about the reactions which occur in the generator, and the effect of pressure on them. This applies particularly to the reactions leading to the synthesis of methane, which is the main enriching component in the product. The mechanism and rate of methane formation in pressure gasification is being studied to provide a better understanding of the Lurgi gasification process, and to define the lines along which an improved gasification process could be developed.

With this end in view equipment has been installed to study the reactions which occur when brown coal, brown coal char, or inert materials are brought into contact with hydrogen-carbon monoxide mixtures under pressures up to 50 atm., and at temperatures up to 900° C. The reactor employed is designed to handle the solids in a fluidized state to enable the temperature in the reaction bed to be closely controlled and to permit of continuous feed and withdrawal of solids.

A series of experiments has been planned to determine the contributions made to methane synthesis b coal hydrogenation, carbon hydrogenation, and ga phase synthesis, either catalysed or uncatalysed, and t determine the kinetic features of each set of reaction One immediate result of this work will be an evaluation of the Dent two-stage pressure gasification proces as applied to brown coal.

Initial test runs with this equipment will commenc in the near future.

(*c*) *Fundamental Studies Related to the Gasificatio of Coal.*—Other fundamental work is in progress o other reactions important to coal gasification. A attack is being made on the difficult problem of determining the effect of pressures up to 50 atm. on th rate of the primary steam-carbon reaction. It i believed that the techniques being used are a considerable advance on previous work in this field.

The pore structure and surface area available fo reaction of char and coke samples are being determined. A helium density apparatus has been constructed to determine the true densities of porou materials, and it has already been used to investigat time-density changes which occur when brown coa is carbonized over a range of temperatures. Apparen surface areas for carbon and other porous solids hav been determined by means of a Carman gas-diffusio porosimeter. Measurements of the structure of macro pores in carbon samples have been made with a low pressure mercury penetration apparatus. To determin pore structures having diameters as small as 40-60 Å new mercury penetration apparatus capable o operating at a pressure of 30,000 lb./sq. in. has bee constructed. The results obtained should provid valuable information on the actual pore structure o the solid samples and also help to clear up anomalie in surface areas determined by methods based on th heat of wetting and on the adsorption of nitrogen.

This work is aimed at a better understanding of th way in which the method of preparation of carbo samples affects their reactivity to gasifying agents and the mechanism of carbon attrition durin gasification.

In continuation of the work on the catalysis by coa ash constituents of reactions occurring during the gasification of coal, apparatus has been constructed to study the catalysis of methane synthesis by coal ash.

(*d*) *Fluidization Studies.*—To provide information required for the design of experiments in Section 7(*a*) of this Chapter, an investigation of the fluidization characteristics of finely divided brown coal and brown coal char is in progress. Previously it has been necessary to determine the optimum conditions for fluidization of a particular sample of material by visual observation of its behaviour when fluidized in a transparent-sided apparatus. These results must then be extrapolated to actual reactor conditions, in which the fluidizing gas may be under high pressure, at a high temperature, or of a different composition from that used in the initial test. Although methods of extrapolation have been proposed, they are not supported by any conclusive experimental evidence. In addition the movement of solids observed in the transparent test apparatus is that close to the walls and it is doubtful if it is representative of the whole bed of material.

A method has been devised for the quantitative measurement of the degree of homogeneity of the solids-gas mixture in a fluidized bed and it is being used to check proposed methods of extrapolation of fluidization test data. By means of a sensitive probe which can be easily inserted into an actual fluidized reaction system it will be possible to confirm that the conditions aimed at are actually being achieved.

8. Utilization of Solar Energy.

(Central Experimental Workshops.)

Work which had been commenced the previous year on the performance of flat-plate solar absorbers in Melbourne was continued and a prototype solar water heater embodying a flat-plate absorber was constructed. The performance of this unit resulted in the development of what is believed to be a satisfactory design for use under Australian conditions. It is hoped that a number of these can be installed in various locations throughout the country where their performance would be further observed.

It appears that correct design from the point of view of flow conditions in the absorber and the connect-ng piping is important in the efficiency of heat transfer. After allowing for the capital cost of the nstallation, the solar water heater looks economically attractive compared with other forms of heating up to temperatures of the order of 135° F., which is adequate for domestic and many industrial applications. The efficiency of the absorber, however, drops off rapidly above this temperature, and it is unlikely to be economic except where other forms of heating are very expensive.

XXI. PHYSICAL METALLURGY.

1. General.

A programme of research on specialized projects in the field of metallurgy is undertaken at the Section of Physical Metallurgy established in the Research School of Metallurgy at the University of Melbourne under Professor J. N. Greenwood. This work is described below. Work on metal physics is in progress within the Division of Tribophysics (*see* Chapter XXII.).

The work of the Division of Industrial Chemistry on foundry sands is reported in Chapter XVIII., Section 4.

Section of Physical Metallurgy.—Extensions to the Baillieu Laboratory were completed during the year and have made much new laboratory space available o the Section.

The main investigations described in the previous Annual Report have been continued. The titanium project has been extended to include a study of the deformation and mechanical properties of titanium and its alloys at both normal and elevated temperaures. This strengthens the link between the titanium nvestigations and the other main project of the Section, namely, researches on the mechanism of deformation in metals. The new investigation also develops the engineering applications of the earlier, more fundamental researches on titanium alloys.

The Section has continued to participate in the raining of undergraduate and post-graduate students n the Baillieu Laboratory. It has also continued to answer inquiries on metallurgical problems submitted by industrial concerns and other government departments.

2. Titanium and its Alloys.

(Section of Physical Metallurgy.)

(*a*) *Alloys.*—The effects of alloying elements on the allotropic transformation in titanium have been nterpreted in terms of the electron theory of metals; the Brillouin zone characteristics of the allotropes of titanium are probably amongst the most important factors which determine the effects of alloying elements on the transformation temperature.

During the year work was commenced on an investigation into the effects of alloying on the mechanical properties of titanium at temperatures in the range 20-600° C. The alloying elements covered in this work were aluminium, tin, zirconium, oxygen, and nitrogen. All these elements dissolve to an appreciable extent in the α (low-temperature) form of titanium and they yield solid-solution alloys which are stable in the range of temperature studied. It was considered that an examination of the mechanical properties of these α solution alloys would materially assist in establishing a basis for the systematic development of titanium alloys for engineering applications.

Aluminium appears to have beneficial effects on the mechanical properties of titanium at both normal and elevated temperatures. The effects of zirconium were also appreciable, while large additions of tin caused intercrystalline brittleness at temperatures above 400° C. Alloying with oxygen and nitrogen tended to make titanium brittle at normal temperatures without any significant improvement in strength at elevated temperatures. Some of the effects appear to be due to strain-aging; this possibility, and the delaying of strain-aging by suitable alloying, are being investigated.

(*b*) *Reactions with Oxygen.*—The study of the kinetic oxidation of titanium at elevated temperatures has been extended to include other factors. Decrease in pressure from 700 to 100 mm. Hg. reduces the oxidation rate by less than 5 per cent. Heavy deformation has little effect, but the influence of grain size is appreciable.

A small arc furnace has been constructed for the preparation of extremely pure microsamples of titanium alloys.

(*c*) *Chemical Studies.*—A polarograph has been built and exploratory work on its use for the determination of impurities in titanium has been carried out.

A method of descaling and polishing titanium chemically with pyrophosphoric acid has been developed.

3. Deformation of Metals.

(Section of Physical Metallurgy.)

The study of the creep of lead and its alloys has been continued. The cracking of lead-tellurium alloys during creep appears to be associated with inhibition of grain-boundary migration and variations in grain size. Factors affecting the recrystallization of pure lead during creep have been investigated. The results indicate that the strain at which recrystallization commences is sensitive to the thermal and mechanical history of the specimens but not to rate of strain nor, therefore, to the observed types of deformation. The effects of prior strain by creep, of grain size, and of specimen size on the creep of lead and lead-thallium alloys are also being studied.

Experiments have been completed on the comparison of various methods of revealing sub-grains in aluminium and zinc and the general development and assessment of special optical techniques continued.

Apparatus has been designed and constructed and preliminary experiments made for the study of the mechanism of deformation of titanium at elevated temperatures *in vacuo*.

XXII. TRIBOPHYSICS.

1. General.

The Division of Tribophysics has developed from the former Lubricants and Bearings Section established during the war to assure Australian engineering industry of essential information in the manufacture of bearings for aero and other engines. The original investigations have been continued and extended to include fundamental studies in metal physics, the surface physics and chemistry of the solid state, and reaction kinetics. Major advances have been made in the knowledge of distortions in metals produced by plastic deformation, of phase changes in metals, and of the mechanism of oxidation reactions.

Division of Tribophysics.—The work of the Division has been continued along the general lines described in the last Annual Report. The Division is now completely installed in its new laboratory situated in the grounds of the University of Melbourne. The new building was opened officially by the Minister in Charge of the Organization, the Rt. Hon. R. G. Casey, C.H., D.S.O., M.C., M.P., on 10th December, 1953.

As in previous years, the Division has co-operated with the Chemistry, Metallurgy, Physics, and Engineering Departments of the University and is indebted to these Departments for the use of many facilities.

Advice and assistance have been given frequently to numerous industrial firms, government organizations, departments of various universities, and other Divisions of the Organization. The range of subjects—lubrication, bearings and bearing metals, wear, metals technology, electrolytic polishing, electronics, combustion, and gas analysis—illustrates the way in which the fundamental investigations of the Division are related to practical applications.

Officers of the Division have continued to act on various committees, in particular, the C.S.I.R.O.-Department of Supply Engineering Group Committee. The metallurgical colloquia held with other metallurgical groups continue to be an important medium for the exchange of specialized knowledge.

2. Properties of Surfaces.

(Division of Tribophysics.)

The work on the physics and chemistry of solid surfaces is concerned mainly with the influence of the arrangement of the atoms in the surface on its properties, the behaviour of molecules absorbed in solids, and practical aspects of friction and lubrication.

(*a*) *Bearing Testing.*—Because of the transfer to the new laboratory the apparatus has had to be largely reconstructed. The parallelogram type of balance used for measuring bearing friction torque has been modified to allow of twice the bearing load previously available. Provision has been made for the application and measurement of a torque tending to misalign the bearing and for the admixture of boundary lubricants with the test oil as it enters the bearing. Recalibration of the balance and associated equipment is almost complete. The work on the effects of geometrical factors and surface finish on performance will be continued.

(*b*) *Adsorption.*—The phenomena of adsorption on solid surfaces are being investigated by studies of the adsorption of long-chain organic compounds on solids of various types.

The adsorption of a monomolecular layer of a compound from its aqueous solution renders the surface hydrophobic to the solution only when the concentration is within certain limits. These critical concentrations are almost independent of the nature of the solid but vary widely for different compounds in solution. The results suggest that the lower and upper limits are associated respectively with the adsorption of the monomolecular layer and the formation of micelles in the bulk of the solution.

The behaviour of mono- and multimolecular layers of insoluble compounds on different surfaces has been studied by sensitive radio-tracer techniques. A radioactive atom is incorporated in the organic molecule and the distribution of the molecules over the surface is followed by a special Geiger counter and by auto radiography. It has been widely supposed that unde certain conditions organic compounds will diffuse ove solid surfaces. However, true surface diffusion o long-chain compounds over macroscopic distances ha been shown not to take place even at temperature well above the melting points of the compounds. A temperatures near the melting point desorption of th compound begins to occur and in favorable cases th desorbed material may travel through the vapour phas and be re-adsorbed on another part of the surface This process is probably responsible for a number o earlier claims that surface diffusion had been observed

(*c*) *Reactions in Monomolecular Films.*—The stud of mixed monomolecular layers of long-chain fatt acids and their metallic soaps is hampered by th difficulty of preparing films of known composition fo transfer to the solid from the surface of water. Thi has necessitated an investigation of the mechanica properties and composition of films of long-chain compounds spread on solutions containing metallic ion The results show that with stearic acid chemica reactions between the film and the ions convert th acid into the corresponding soap. The degree of conversion and the nature of the soap produced depend i a sensitive way on the pH of the solution. Thus wit careful control of the pH, films of a required soa content may be prepared by this method.

(*d*) *Catalysis on Single Crystal Surfaces.*—Th catalytic properties of a solid depend on the geometrica arrangement of the atoms in its surface. Very littl exact information on the effect exists since it i difficult to isolate it from other factors. The difficult has been overcome by a study of catalysis on th surfaces of differently oriented single crystals of th same metal. The activation energy for the decompos tion of formic acid on silver depends strongly on th crystal orientation, the value characteristic of face parallel to the (110) plane being almost double tha obtained with faces parallel to the (111) plane. Th effect of orientation on the overall rate of reactio is relatively small since the alteration in activatio energy is compensated by a large variation in th entropy of activation. The kinetic parameters obtaine with the polycrystalline metal have roughly the value expected from a random orientation of crystals; specifi effects of the crystal boundaries appear to be smal

3. Metal Physics.

(Division of Tribophysics.)

The aim of the work is to obtain a better unde standing of the plastic properties of metals and of th mechanism of phase changes. This knowledge wi make it possible to state the best conditions of material for use in practice, and widen the rang of materials available to industry.

(*a*) *Plastic Deformation.*—It is generally accepte that plastic deformation of metals occurs by the move ment and multiplication of lattice imperfections know as dislocations. The interaction of dislocations i motion is believed to give rise to two other types o imperfections: vacant lattice sites and interstitia atoms. During deformation not quite all the energ expended is released as heat; a small percentag remains in the metal and is associated with the impe fections produced by deformation. Measurements o this stored energy and observation of the manner o its release when the deformed metal is heated therefor provide information about the imperfections present By combination of such measurements with those o other properties, such as resistivity, hardness, an macroscopic density, the contributions to the store energy by the various types of imperfection may b further distinguished. Other approaches to the proble

e through the measurement of the distribution of
tensity in X-ray diffraction patterns from deformed
etals and the study of the movement of crystal
undaries during annealing after deformation.

(i) *Energy Stored in a Metal During Deformation.*
-For pure copper deformed in torsion the results of
rly experiments indicated that practically no libera-
on of energy occurs below the recrystallization tem-
rature. This suggests that in this case the only
ored energy measured is that associated with disloca-
ons. The result has now been shown to be independent
the heating rate and it is obtained when the metal
deformed both in tension and in compression. It is
erefore not occasioned by the inhomogeneity of
rsional deformation. That this release of energy is
sociated with recrystallization has been established
hardness, resistivity, and density measurements,
d X-ray and metallographic examination.

Measurements of energy stored in deformed nickel
ve continued with improved methods of measuring
e changes in electrical resistivity and density
sociated with the various stages of energy liberation.
pproximately 60 per cent. of the stored energy is
erated before recrystallization. The release of the
st 40 per cent. is associated with an increase in
nsity and a loss of approximately 40 per cent. of the
crement in electrical resistivity due to deformation.
hese results suggest that part of this energy release is
e to the disappearance of vacancies. Calculations
sed on the assumption that the metal is an aggregate
spherical "grains" and that the vacancies disappear
diffusing to the "grain boundaries" agree very well
th the experimental results. A further 20 per cent.
the stored energy is liberated slowly in a temperature
nge in which the decreases in electrical resistivity
d hardness are small. This release is considered to
due to a "recovery" process involving rearrange-
ent and annihilation of dislocations. The remaining
per cent. of the stored energy is released con-
rrently with recrystallization. As with pure copper,
e manner in which the stored energy is released is
dependent of the heating rate and is not influenced
changing the mode of deformation from torsion to
nsion.

With arsenical copper about 40 per cent. of the
ored energy is liberated before recrystallization.
ost of this release occurs without any change in hard-
ss, electrical resistivity, or density. The remaining
per cent. of the stored energy is released concurrently
ith recrystallization. For this material it appears
at vacancies make no contribution to the stored
ergy and that the energy release prior to recrystal-
zation is due to "recovery". The total energy stored
higher than for pure copper. This indicates that
fference in the purity of materials is responsible for
e discrepancy between earlier English work and the
esent results on pure copper.

(ii) *Shape of X-ray Interference Lines.*—Plastic
formation of a metal produces broadening in the lines
its X-ray diffraction pattern. Two causes con-
ibute to the effect: distortion of the crystal lattice
d reduction in particle size. The two phenomena
n be separated by Fourier analysis of the line shapes.
his treatment has been applied to measurements of
e line shapes of nickel filings annealed at various
mperatures, with the object of correlating the degree
lattice distortion with the amount of stored energy
easured directly.

(iii) *Changes in Electrical Resistivity Due to Cold-
orking.*—The change in resistivity produced by cold-
orking has always been regarded as independent of
e temperature at which the resistivity is measured.
ery accurate measurements made by a method
eveloped in collaboration with the Division of Electro-
chnology have shown, however, that the difference in resistivity between the deformed and the annealed metal decreases with increasing temperature. It has been concluded from this that the thermal vibration of the atoms is influenced by the lattice distortion introduced by cold-working.

(iv) *Interaction Between Adjacent Crystals in a Metal Undergoing Deformation.*—The influence of a crystal on its neighbours during deformation has been followed by observation of slip lines in the surface and internal structures developed by etching. Removal of known thicknesses of material from the surface and comparison of the new etched surface with the original show that the continuation of slip lines from one crystal across a boundary into another is not merely a surface effect. The geometry of the crossing of slip lines has been determined. Other characteristics of deformation on the surface have also been shown to be present in crystals embedded in a matrix of others. The results demonstrate that deformation of crystals exposed at the surface is not essentially different from that of crystals entirely surrounded by others.

(v.) *Kinking and Twinning.*—A detailed study of the traces of twins and the kinks which accompany twinning has been made on cleavage faces of zinc single crystals and on sections cut normal to the traces of twins in the basal plane. On this basis a mechanism has been suggested for the growth of a twin in layers and the formation of the kink by the accumulation of dislocations of one sign.

(vi) *Recrystallization.*—The movements of crystal boundaries in non-cubic metals during annealing can be observed with polarized light. The possible correlation of the movements with surface markings produced by deformation is being studied. The surface markings are recorded accurately by a specially developed replica technique so that they may be compared later with observed movements of the boundaries. Special techniques have also been worked out for deforming the specimens and heating them uniformly on the stage of the microscope.

(*b*) *Phase Changes.*—Phase changes in solids are of two types. In the first type the change takes place by diffusion, i.e., nucleation and growth of the new structure are effected by means of the thermal movement of the atoms. In the second type, known as martensite transformations, thermal movement plays no part and the change can occur extremely rapidly at low temperatures. The transformation occurs by small displacements of atoms relative to each other so that each atom in the new structure has the same neighbours as it had in the old.

(i) *Diffusion.*—In a theoretical study experimental results obtained previously in the Division on self-diffusion in tin have been interpreted in terms of possible mechanisms. It appears that diffusion in a direction parallel to the tetragonal axis is dominated by the movement of interstitial atoms, while diffusion perpendicular to this axis is due mainly to the migration of vacancies.

(ii) *Martensite Transformations.*—In this type of phase change the atomic displacements can be deduced from various observable geometrical features of the transformation. A general theory has been developed which accounts for the geometrical properties of a number of individual transformations. The theory has now been shown to predict successfully the geometrical properties of transformations of body-centred cubic structures to close-packed hexagonal structures in titanium and a copper-aluminium alloy, and those of the transformation of the body-centred cubic to orthorhombic structure in a gold-cadmium alloy. The experimental investigations of the order-disorder transformation in copper-gold alloys and of precipitation from the supersaturated α-solid solution in copper-beryllium alloys, though not yet complete, are sufficiently advanced to indicate that these changes are geometrically similar to martensite transformations.

4. Reaction Kinetics.

(Division of Tribophysics.)

The kinetics group has been concerned mainly with two problems—

(*a*) the study of the kinetics of oxidation of organic compounds, and

(*b*) the measurement of thermal conductivities of organic vapours.

(*a*) *Kinetics of Oxidation of Organic Compounds.*—Oxidation by the atmosphere contributes largely to the deterioration of numerous organic materials, for example, lubricating oils, rubber, and high-octane petrol. Highly complex chain reactions are involved. In many cases the intermediate formation and decomposition of peroxides greatly influence the progress of the reaction. Oxidations in the gas phase, e.g., those responsible for knock in the petrol engine, are also influenced by the transitory production of aldehydes. Details of the reaction mechanism are obscure in all but the simplest cases. Two aspects of the problem have been studied: (i) the mechanism of oxidation of gaseous hydrocarbons, and (ii) the kinetics of decomposition of benzoyl peroxide in the presence of antioxidants.

(i) *Mechanism of Oxidation of Gaseous Hydrocarbons.*—The results of kinetic and analytical experiments with propylene suggested that the early development of the reaction is controlled by the formation and oxidation of formaldehyde and higher aldehydes; subsequently, higher aldehydes alone are important. The oxidation of *iso*butane is being investigated. The kinetic characteristics of the reaction are broadly similar to those of propylene oxidation, but detailed kinetic experiments have revealed important differences. Interpretation of the kinetic properties awaits the results of analytical investigations now in progress.

(ii) *Effect of Antioxidants on the Decomposition of Benzoyl Peroxide.*—Peroxide molecules frequently decompose by fission into two free radicals. According to circumstances, the radicals may initiate chain reactions leading to oxidation of other substances or to decomposition of more peroxide. Both chain reactions are eliminated by certain molecules (anti-oxidants) which react rapidly with free radicals. The effects of numerous antioxidants on the latter reaction have been studied using benzoyl peroxide. Polynuclear hydrocarbons, quinone, and picric acid inhibit the decomposition to a limiting rate. The inhibiting action of phenols, however, is counteracted by an accelerating effect. Kinetic analysis and photo-chemical experiments have shown that this results from a direct reaction between peroxide and phenol molecules. Contrary to the generally accepted view, free radicals are not involved.

(*b*) *Thermal Conductivities of Organic Vapours.*—Measurements of the thermal conductivities of gases and vapours provide information on the nature of molecular collisions. The conductivities of a number of vapour mixtures have now been investigated. For mixtures of simple non-polar compounds the conductivity varies approximately linearly with composition, as is to be expected on theoretical grounds. However, for mixtures of polar with non-polar vapours the conductivity-composition curves exhibit pronounced maxima. The results throw light on the dynamics of collisions between dissimilar molecules.

XXIII. NATIONAL STANDARDS LABORATORY.

The maintenance of the Commonwealth standards measurement is shared by the Divisions of Metrolo Physics, and Electrotechnology, which together co prise the National Standards Laboratory.

Work referred to in the last Annual Report, the international comparison of end standards length arranged by the International Bureau Weights and Measures, has been continued. The standards have been measured in the Laboratory at the Bureau and are now back at the Laborat for the final series of measurements.

Work arranged by the Bureau, on an internatio comparison of temperature standards in the reg below 630° C., is in progress. The Laboratory collaborating with the National Physical Laborato England, in a comparison of temperature standards the optical pyrometer range, i.e., above 1,063° C.

Two further *Test Pamphlets* giving details of work of the Laboratory and the tests carried out h been issued. Those issued so far are: No. 1—H hygrometry, and viscometry; 2—Optics and pho metry; 3—Electricity and magnetism; 4—Engineer metrology; 5—Materials testing machines mechanical instruments; 6—Physical instruments.

XXIV. METROLOGY.

1. General.

Among the basic factors in modern engineer production are uniformity of quality and performance. Industry therefore needs to be able make accurate measurements. The equipment used this purpose must be regularly controlled, check and calibrated against appropriate working standar These in turn require periodical calibration in terms the national standards, some of which are maintai by the Division of Metrology.

Division of Metrology.—The Division, as part the National Standards Laboratory, is responsible the Commonwealth standards of measurement length, mass, and time interval, and the associa physical quantities.

The main effort of the Division is directed towa statutory and industrial requirements regard national standards, but research on problems precision measurements in metrology and appl mechanics is also undertaken.

The most important project of the year was ag work for an international intercomparison arran by the International Bureau of Weights and Measu All the labour put into the earlier work was destro by the unfortunate mishandling of the case in transp when bars and platen were irreparably damaged. enable the Division to take part in the intercomparis the International Bureau quickly made available f end bars and the work was completed within necessary time.

Another important piece of work, done for Division of Tribophysics, was a very accurate det mination of changes in density of strained mater on annealing.

Very great interest was aroused by the exhibits demonstrations at the two open days held at Laboratory during the year and the number of visit reached the limit that could be handled by the staf

Addresses have been given to technical institutio and members of the staff lecture in the Departme of Production Engineering of the Sydney Techni College; officers have taken part in the work of Standards Association of Australia, the Nation Association of Testing Authorities, and the Optic Munitions Technical Advisory Committee.

2. Length and Associated Quantities.

(Division of Metrology.)

(*a*) *Standards.*—Maintenance of the Laboratory's line and end standards of length has continued. A metre line standard of nickel and a 20-in. line standard of nickel steel have been added to the range of working standards.

(*b*) *Universal Comparator.*—This comparator has been used extensively for calibrating both the Laboratory's own working standards of length, and scales for outside organizations. The temperature of the scales during calibration can now be measured, using the Mueller bridge and associated resistance thermometers, with an accuracy of ±0.004° C. on the International scale, whilst temperature differences between the scales may be measured to ±0.001° C.

(*c*) *Geodetic Base.*—The 4-m. standard has been calibrated and used in a preliminary calibration of the geodetic base and of three of the Laboratory's standard tapes. The values obtained for the standard tapes were in satisfactory agreement with the original values obtained by the National Physical Laboratory, England.

Investigations are being carried out on the method of determining the coefficient of thermal expansion of tapes, where the tape is heated by an electric current. Determination of the temperature of the tape by means of thermocouples was considerably improved by the use of nichrome-constantan instead of copper-constantan couples.

The geodetic base has been used to calibrate a number of tapes of various lengths for other organizations.

(*d*) *Dividing Engines.*—The use of both the linear and circular engines has again been restricted. However, work completed on these engines includes the graduation of several surveying tapes for the Department of the Interior, two 40-in. line standards (width of graduation lines approximately 0.001 inch), and several circular scales of various types. Many rulings were made for the investigation into graticule production.

(*e*) *Gears and Gear Hobbing Equipment.*—A number of marine turbine gears and gear couplings have been examined for the Department of the Navy. Experience in this work has shown the need for mproved portable measuring instruments and the development of suitable instruments is being underaken.

(*f*) *Interferometry.*—A series of mercury and krypton isotope lamps have been received and their performance is being studied.

(i) *International Calibration.*—Four end standards 25, 50, 75, and 100 mm. in length were calibrated and forwarded to the Laboratory by the International Bureau of Weights and Measures, France, for the purpose of an international comparison by interferometry. The Bureau's measurements were subsequently reported as agreeing with hose done at this Laboratory to 0.01 μ, or within half a millionth of an inch. As these measurements were done with different types of interferometers and different light sources the agreement is very satisactory. The end bars have now been returned to his Laboratory for a further calibration to check heir stability.

(ii) *Kosters-N.S.L. Interferometer and Wavelength Determinations.*—The interferometer continues to be sed on a comparison of cadmium, krypton, krypton 6 isotope, and mercury 198 isotope lamps and their uitability as sources of absolute standards of length.

(iii) *One-Metre Interferometer.*—Progress has been made with the mechanical design work and the vacuum chamber is now being made. Experimental tests with multilayer dielectric films in Fabry-Pérot reflection interferometry indicate their superiority to silver films.

(iv) *Multiple-beam Interference Comparator.*—This comparator with a capacity of 1 m. is nearing completion. It will enable highly precise comparison of end standards to be made in terms of light waves.

(v) *Interference Microscopy.*—As reported last year, a simple multiple-beam interference microscope has been set up permanently and has been used extensively during the year on problems of surface finish of slip gauges and ball bearings, properties of thin films, and optical thickness of anthracene crystals 1 μ thick, and on studies in liquid surface interferometry.

A compact two-beam interference microscope is being developed for routine testing of the surface contours and face angles of diamond indenters.

(vi) *Phase Loss Studies.*—The contributions that the nature of the material of a surface and the surface structure make to phase loss at reflection are being investigated. An expression has been derived relating these factors to each other and experimental verification is in progress.

(vii) *Liquid Surface Interferometry.* — The measurement of surface tension by interferometry has been further studied.

(viii) *Adhesive Films Between Metal Surfaces.*—Measurements of the contact error arising in wringing are being made using multiple-beam interference.

(ix) *Graticule Production.*—The preparation of graticules by the double evaporation of zinc and chromium and of aluminium and chromium has been developed successfully. In co-operation with the Department of Defence Production, the Division has also developed a combined evaporation-photographic method which is now being used successfully on a production scale.

(x) *Effects of Collimation and Oblique Incidence in Length Interferometers.*—An investigation of the effects of oblique rays involved in the use of interferometers for length determinations has been completed. These effects are of considerable importance in the measurement of long lengths now made possible by the use of isotope sources.

(xi) *Wavelength Data and Correction Table for Interferometry.*—Comprehensive tables of wavelength and refractive index data for use in length interferometry have been completed and are being prepared for publication.

(xii) *Multiple-beam Interferometry Studies.*—A study was made of the particle tracks in nuclear emulsion plates. Shrinkage in photographic emulsions and the optical properties of multilayer dielectric films have also been studied. A technique for measuring vibratory displacements by examination of the resultant intensity pattern of vibrating fringes under multiple-beam conditions has been investigated theoretically and experimentally.

(xiii) *Equipment and Facilities.*—Equipment for the measurement of temperature with a precision of about 0.001° C., by means of platinum resistance and thermocouple thermometry, has been assembled and tested. Provision has been made for rapid check calibration of galvanometers and thermocouples.

A variable gap Fabry-Pérot interferometer has been completed for precision vacuum wavelength determinations.

A travelling microscope for measuring photographic plates and film has been completed and is now in use.

(*g*) *Capacitance Displacement Meter.*—Displacement meter type B has been completed and has been applied to the study of vibrations in machinery, the measurement of the sensitivity of vibrating reeds, the measurement of force and pressure, and the autographic recording of periodic errors in lathes.

The recorder amplifier has been completed. This instrument enables the capacitance displacement meters, or any other high-impedance source of voltage, to be used in conjunction with an ordinary recording milliammeter. The maximum sensitivity is 100 mV. full scale, and a stability superior to the capacitance displacement meter has been achieved.

(*h*) *Study of Noise in Ball Bearings.*—Air-borne noise from a number of types of ball bearings has been investigated. A good quality microphone was used to convert the acoustic output from the bearing into an electrical signal. The following equipment was developed to enable the electrical signal so obtained to be analysed: (i) a high gain amplifier with good signal: noise ratio; (ii) a tunable selector to isolate individual frequency components in the noise spectrum studied, i.e., 20-9,000 c/s.; (iii) a set of filters to divide the spectrum into three bands, namely, 20-150, 150-1,200, and 1,200-9,000 c/s.

This equipment enabled the following measurements to be carried out: (i) in the same bearing, comparison of the noise levels in any two of the three bands of the noise spectrum; (ii) comparison of the noise levels of two bearings; (iii) measurement of the frequency and relative amplitude of individual noise components in the range 20-9,000 c/s.; (iv) study of the waveforms of the noise output on a cathode-ray oscilloscope.

(*i*) *Abrasives and Lapping.*—Laboratory measuring equipment was serviced and a number of new pieces of equipment completed, including a 14 by 10 in. fully-lapped surface plate, and special slip gauges.

(*j*) *Photogrammetry.*—The problem of adjusting cameras in which the distortion curve is asymmetric has been studied in conjunction with a firm engaged in photogrammetry who are making flight tests on the cameras.

(*k*) *Measurement of Time Interval.*—(i) *Rating of Watches.*—Methods and equipment for checking stopwatches have been developed in which the observer's personal equation is eliminated. Intervals are measured on an electronic counter operating at 1,000 c/s. and the starting and stopping of the watch actuates the gating circuit starting and stopping the counter.

(*l*) *Measuring and Consultative Service.*—The volume of this work has remained high. Tests were made on a wide range of gauges, measuring instruments, and other equipment such as surveying tapes, circular scales, graticules, surface finish specimens, and lathes. Increased numbers of inquiries on precision measurement, interferometry, and related matters have been answered. Laboratory measuring equipment has been designed and manufactured.

3. Mass and Associated Quantities.

(Division of Metrology.)

(*a*) *Standards of Mass.*—Production of metric standards of mass has been continued using electrolytic polishing. The method has been found to give satisfactory results in the adjustment of standards as small as 10 g. to within 10 parts per 1,000,000.

Intercomparison of several groups of standards has indicated that the values of all weights in regular use have remained satisfactorily constant.

A balance of 1 kg. capacity was constructed, with means for mechanically interchanging the loads on the pans without opening the balance case.

(*b*) *Investigations on Balances.*—The 200-g. balance used for mass standards work has been fitted with a modified design of stirrups and synthetic sapphire stirrup planes, and has since performed satisfactorily.

The increasing use of analytical balances with automatic weight-loading mechanisms has led to an investigation of the possibility of standardizing the weights in such balances to a satisfactory order of accuracy without removing them from the balance. A satisfactory procedure has been developed for one balance of this type.

(*c*) *Density Measurement.*—The main project in this field, on changes occurring in the density of strained metal specimens on annealing, was studied for the Division of Tribophysics. Measurements were made on five specimens, three of nickel and two of copper, and density changes of 0.00015 g./ml. were readily detectable.

The basic equipment for density measurement has been improved by the provision of a new control panel and circulating pump.

4. Applied Mechanics.

(Division of Metrology.)

Close liaison has been maintained with the engineering industry in New South Wales the better to identify industrial problems, and hence to shape the structure of engineering research programmes. Industry is turning increasingly towards the Division for advice and assistance. Available staff was concentrated upon routine calibration of testing machines, for which demands have been steadily increasing. Experience has pointed to the need for extending the range of proving equipment and also for the provision of facilities for dead-weight calibration of proving devices to meet the Division's statutory commitments. Features of the year's work were: assistance given to the telecommunications industry in New South Wales in engineering design analysis; active participation in the proceedings of the International Institution for Production Engineering Research in Europe; and work on vibration isolation and dynamic balancing.

(*a*) *Machining.*—The nucleus of equipment required for machining research has been installed, and includes an 8 horse-power high-speed lathe suitable for carbide turning, and grinding and lapping machines for reconditioning both high-speed steel and carbide-tipped cutting tools. Techniques developed in vibration research were successfully applied to improving the vibration characteristics of the lathe.

Two review papers were presented at the annual meeting of the Institution for Production Engineering Research at Aachen, Germany, in April 1954. One dealt with overseas developments in surface finish, especially the influence of finish on function, and the factors affecting finish in machining; the other was a critical examination of production engineering research in Europe, Great Britain, and the United States of America.

The validity of the Schlesinger Index for machinability is being investigated. This test aims at giving an estimate of expected tool life under given conditions with a particular material, and can be made simply and quickly on a good lathe in the average workshop with little specialized equipment.

Methods for measuring the sharpness of cutting tools are being developed, to study the effect of sharpness on the cutting properties of the tools. Several optical and mechanical methods for determining the contour of the cutting edge have been explored.

A patented method of surface finishing, referred to the Division for investigation, has been examined in principle and compared analytically with the well-known superfinishing process. An experimental head as been built to compare the results obtained in prac- ice with the two methods.

(b) *Engineering Design Analysis.*—Officers of the ivision last year took a leading part in the activities f a Working Group established by the Sydney Section f the Institution of Production Engineers to analyse esign and drawing practices in New South Wales. echniques previously developed by the Division, inluding the "design problem" technique for conducting he analysis, were adopted and applied. The report on his analysis has been published in the April 1954 roceedings of the Institution of Production Engineers, ondon.

A Sydney telecommunications firm desiring to apply he modern practices of engineering design analysis ater requested the help of the Division. It was decided hat a course on the new principles should be offered o the Sydney firms in the telecommunications indusry; by giving selected designers and engineers a conentrated course of study in the application of such rinciples, the dissemination of up-to-date information n engineering design analysis would be accelerated.

The trend towards stricter control over the functionng performance of products demonstrates the need for better assessment in design of the tolerances permisible from the functioning viewpoint, and at the same ime provides more accurate knowledge of the natural" tolerances attainable by machine tools and roduction processes. Techniques are now being eveloped for determining the natural tolerances and requency distributions corresponding to operations on nachine tools. Tests have been made on the automatic crew machine of a Sydney firm who have co-operated n this research.

(c) *Vibration Isolation.*—The principles and pracice of vibration and shock isolation have been investiated, following continued demands for assistance in olving vibration troubles. A survey of the available nformation has been completed, and experimental work as been done to check some of the published data.

Assistance has been given to industrial and other nquirers in solving problems involving the mounting of alvanometers, balances, and optical equipment, n selecting suitable locations for sensitive equipment, nd in identifying and isolating sources of vibration. A special type of vibration-isolating table for galvanoneters has been designed for general use in the aboratory.

(d) *Vibration Measurement.*—Work has continued n the development of vibration measuring facilities for se in the analysis of vibration problems in industry nd within the Laboratory. Main attention has been iven to capacity type vibration transducers. Further seful experiences has been obtained in the use of the wo experimental transducers referred to in the last Report.

The characteristics of capacitive transducers employng a variable air gap for vibration and other measurenents have been further evaluated for sensitivity and rrors. Preliminary work has been done on developing new form of capacity vibration transducer using ariable area, which offers certain advantages over the ariable gap type.

(e) *Dynamic Balancing.*—Many demands were reeived from industry for the dynamic balancing of otors, discs, and other components and for advice on alancing procedure.

An important improvement evolved in dynamic alancing technique should enable dynamic balancing o be done with greater precision and considerable aving in time because of the fewer runs of the rotor equired.

A new demand from industrial sources is for the verification of dynamic balancing machines used for balancing turbine rotors and other large components. The basic requirements are being examined and examination of the machine has commenced.

(f) *Vibrometer Calibration.*—A serious deficiency in the facilities for vibration work is the lack of adequate means for calibrating vibrometers. Present needs are being partly met by improvisation. Suitable driving equipment has been ordered, and this will be incorporated into a vibrometer calibrater, designed as a permanent installation.

(g) *Measurement of Physical Quantities for Industry.*—(i) *Force.*—To meet requests for the examination of testing machines, steps are being taken to equip the Division with an adequate range of proving instruments which will ultimately enable the largest testing machines installed to be calibrated. To provide for calibrating the proving instruments themselves, consideration is being given to acquiring 50-ton and 5-ton dead-weight testing machines.

(ii) *Pressure.*—A numerical method has been developed for calculating the effective hydraulic area of a dead-weight pressure gauge tester, taking into account variations in diameter revealed by precise measurement of the plunger and cylinder.

(iii) *Hardness.*—The device developed for verifying Rockwell hardness machine depth indicators *in situ* has proved successful and methods have been further developed for the complete verification of hardness testing machines of the Vickers and Rockwell types.

The 150-kg. proving levers have been modified so that when used in measuring indenter loads of hardness testing machines the operating conditions approximate very closely to those in an actual hardness test. The diaphragm type of indenter load-measuring device, employing a capacitance change principle, has also been further developed.

Construction and installation are complete on an N.P.L. precision dead-weight hardness testing machine designed for calibrating the hardness test blocks used for checking the overall performance of Vickers and Rockwell hardness testing machines. Some modifications are being made to this machine.

(h) *Verification of Materials Testing Machines and Other Equipment for Industry.*—The demand for examination of materials testing machines in New South Wales and Queensland has increased over the last few years and this work, together with the examination of engineering instruments and equipment, has occupied a considerable portion of the time of officers of the Division.

(i) *Vibrating Reed Indicator.*—In this type of indicator, as found on proving rings, a vibrating reed is used for determining a reference position for a micrometer screw. The reference position is indicated when the tip of the micrometer screw just interferes with the vibration of the reed. A method has been developed for determining the sensitivity of one of these indicators.

(j) *Spanner Torque and Bolt Tension.*—Inquiries have been received for information on the relationship between the torque applied to a nut and the resulting tension in the bolt. A survey of available information is being prepared.

(k) *Information and Assistance to Industry and Other Organizations.*—Information has been given on a wide range of engineering problems relating to the measurement of force, pressure, torque, hardness, strain, vibration, and friction, engineering design, balancing, limits and fit, tolerances, surface finish, and drawing practice. In addition many special tests have been undertaken for industry.

XXV. PHYSICS.

1. General.

The Organization is engaging in many aspects of physical research within a number of Divisions and Sections. The present Chapter is concerned with the work of the Division of Physics, which forms part of the National Standards Laboratory.

Division of Physics.—The Division is responsible for: maintaining the Commonwealth standards of measurement in heat, light, viscosity, and related fields, and the primary electrical standards of resistance and voltage; testing and calibrating measuring equipment for industry, government departments, and scientific laboratories in terms of the Commonwealth standards; carrying on physical research, both fundamental and applied; advising industrial organizations and scientific laboratories generally on precision measurements and other matters.

Close liaison has been maintained with the International Bureau of Weights and Measures and the National Physical Laboratory of Great Britain in regard to photometric, electrical, and thermometric standards. Considerable progress has been made in setting up standards of viscosity and in methods of measurement, particularly to meet the needs of the petroleum industry.

Of the various researches completed during the year special mention should be made of an investigation of rapid methods for the measurement of soil moisture, required in connexion with the construction of the Adaminaby earth dam for the Snowy Mountains Hydro-electric Authority, and the development of a new absolute method of very high precision and wide applicability for measuring the humidity of gaseous atmospheres.

As in past years officers of the Division have contributed to the work of several governmental and semi-governmental committees.

2. Heat.

(Division of Physics.)

The main fields of work during the year were temperature measurement, hygrometry, moisture content measurement, viscometry, and low-temperature physics. Work on phase nucleation was suspended owing to more pressing needs.

Much assistance has been given to scientific and industrial establishments by calibrating equipment, advising on special problems, designing instruments, and training personnel.

(*a*) *Measurement and Control of Temperature.*—To increase the precision of maintenance of the International Temperature Scale new apparatus has been constructed for the primary fixed points defined by the boiling points of water and sulphur, and a precision manometer is under construction for the measurement of the controlled pressures at which boiling occurs. High gain amplifiers for use with a new resistance bridge and thermocouple potentiometer have been developed. Equipment under construction includes a resistance thermometer intercomparator, an assembly for the completely automatic calibration of thermocouples, and resistance thermometers of new design.

Investigations are proceeding on a number of fixed-point cells which will, it is hoped, provide highly reproducible temperatures intermediate between the primary fixed points on the International Temperature Scale and therefore suitable for international tests of the accuracy of realization of this Scale.

In preparation for an intercomparison of the temperature scales above 1,063° C. maintained at the National Physical Laboratory, England, and at this Laboratory, a recalibration of the sub-standards of temperature measurement in this range is in progress.

The setting up of a temperature scale between 20° and 90° K., in accordance with a proposed extension of the International Temperature Scale, and the provision of facilities for calibrating temperature-measuring equipment down to 20° K. is now well advanced.

(*b*) *Hygrometry.*—Hygrometry is of such industrial importance that particular interest attaches to any new development in this field. A new method for the measurement and control of humidity which will, it is believed, have a wide range of usefulness, has been devised. The detecting element is a small ionic crystal. If such a crystal is exposed to an atmosphere in which the vapour pressure exceeds that of a saturated solution of the salt, water will condense on the surface of the crystal, forming initially a thin film of saturated salt solution. The temperature at which the film remains in equilibrium with the atmosphere, as indicated by the constancy of its electrical resistance, provides an accurate measure of the absolute humidity of the atmosphere. This temperature can be readily determined to 0.01° C. The method lends itself to automatic operation and, providing a suitable crystal is selected, may be used in a wide variety of conditions. It also provides an accurate method for determining the vapour pressures of saturated solutions of ionic solids as a function of temperature and such measurements have already been commenced.

Techniques for the calibration of high pressure frost-point hygrometers have been devised and further work done on an automatic dew-point hygrometer of very short response time.

(*c*) *Moisture Content and Density of Soils.*—Methods suitable for field use in connexion with the erection of consolidated earth structures have been developed for the rapid determination of soil moisture. Field investigations conducted in collaboration with the New South Wales Department of Public Works at the Adaminaby dam site confirmed the laboratory finding that each of the three methods investigated was capable of an accuracy of ±0.5 per cent. moisture content and required 5-10 min. per measurement. It was found that the methods depending on the rapid drying of the soil and on the reaction of the soil moisture with calcium carbide were more suited to field use than that in which soil density is determined; the first two methods have now been applied to selected construction projects.

In rolled earth construction the measurement of soil density is also important. Preliminary tests on the absorption of gamma rays indicate that an instrument designed to measure soil density on this principle should be capable of higher accuracy and be much speedier than the methods at present employed.

(*d*) *Viscometry.*—To meet the recent increase in the quantity and accuracy of viscometric work requested by industry, improved facilities for the precise measurement of viscosities and for examining the viscous behaviour of liquids are being set up. An examination of the accuracy implied in some viscometric specifications in the petroleum industry indicates that a review of these specifications is desirable.

(*e*) *Precipitation.*—The analysis has been completed of experimental results on the sublimation of solid carbon dioxide in supercooled fogs and the resulting production of ice crystals. The findings are of relevance to the process of the artificial production of rain and are discussed in more detail in Chapter XXVIII., Section 8.

(*f*) *Low-temperature Physics, Theoretical Research.*—In the theoretical and experimental investigation of the physical properties of substances at very low temperatures particular attention has been given to the thermal and electrical conductivities of solids and related phenomena. Theoretical work has included the following:—(1) The heat transport equation for pure metals has been solved numerically. (2) The crystal lattice component of the thermal conductivity of metals and alloys has been evaluated in terms of other physical quantities. (3) From the results derived in (2) the form of the coupling between electrons and crystal lattice waves has been deduced for a group of substitutional alloys studied experimentally. (4) A study has been made of the theories of the thermal conductivities of metal in the electrically superconducting and intermediate states. (5) From an analysis of data on the conduction properties of monovalent metals new details of their basic structure have been deduced. (6) It has been shown that the thermoelectric properties of metals and alloys should be significantly affected by the heat conducted by the crystal lattice. (7) The theoretical connexion between the thermal expansion and the thermal conductivity of non-metals at low temperatures is being studied.

The above theoretical studies are of importance in the planning and interpretation of the experimental work at low temperatures.

(*g*) *Low-temperature Physics, Experimental Research.*—(i) *Low-temperature facilities.* — The facilities for low-temperature research have been greatly improved by making liquid helium continuously available for experimental work, the helium liquefier being operated as required to replenish the supply. The liquefaction rate has been increased and maintenance time reduced and, to effect economies in the large quantities of liquid oxygen and nitrogen required for low-temperature work, a liquid air rectification column is under construction.

The present lower temperature limit of the equipment is about 1° K. Lower temperatures are necessary for many investigations and these are usually obtained by the magnetic cooling method. As facilities for measurements in magnetic fields are also required a magnet suitable for both these purposes is under construction.

(ii) *Thermal and Electrical Conductivities.*—To study the transport of heat by crystal lattice vibrations, and to obtain information about the basic structure of pure silver, measurements have been made on the thermal and electrical conductivities of a series of binary alloys of silver with palladium and cadmium.

A new cryostat is being constructed for the study of the thermal conductivity of electrical superconductors. Simultaneous measurements on the same pecimen will be made of the thermal and electrical onductivities in the presence of a transverse or ongitudinal magnetic field.

(iii) *Temperature Measurement.*—Equipment has een set up for the realization of a reproducible emperature scale from 2° to 90° K. It combines hydrogen and oxygen vapour pressure thermometers nd a helium gas thermometer in an isothermal nclosure and will be used initially for the calibration f resistance thermometers for calorimetric measurements on some of the metals whose thermal conducivities have already been determined.

3. LIGHT.

(Division of Physics.)

(*a*) *Photometry.*—(i) *Photometric Standards.*—The international adoption of the black body standard or luminous intensity in 1948, together with an agreed pectral luminosity function, enables photometric tandards to be established anywhere *ab initio*, but for he present the Laboratory will use incandescent lamps s standards. Lamps calibrated by the Bureau International des Poids et Mesures have now been secured nd will serve in future as the Laboratory's reference andards.

(ii) *Seasoning of Tungsten Filament Lamps.*—Using a colour-temperature comparator developed in the Division, the seasoning process of tungsten filament lamp standards has been examined and shown to be one of simple recrystallization of the tungsten filament, during which the resistance decreases, as expected, and there is a decrease in emissivity of 10 per cent. or more at all wavelengths. The investigation also showed that standard lamps can be aged at much lower temperatures than those at which they are intended to operate, with elimination of blackening and conservation of life.

(iii) *Precision Photometer.*—In the past two or three years considerable improvement in the accuracy of photometers has been achieved in the Laboratory by using photoelectric cells as detectors of inequality rather than as measuring devices. Thus a colour-temperature comparator, referred to in (ii), is now in routine use for photometric bench measurements. Another precision photometer involving the polarization of the light has been developed.

(iv) *Heterochromatic Photometry.*—The problem of obtaining a detector having overall spectral sensitivities identical with the standard luminosity function of the eye has never been completely solved, and hence where possible the Laboratory has used spectrophotometric methods for measuring photometric quantities. To improve methods of heterochromatic photometry the Laboratory's recording spectrophotometer is being adapted for the measurement of spectral energy distribution of light sources. This work is preliminary to the establishment of improved standards for the photometry of fluorescent lamps.

(v) *Retroreflectors.*—To meet the needs of manufacturers and to assist road authorities the Laboratory has investigated the optical properties of retroreflectors, their design and testing, and the requirements for their use on warning devices and road signs. The optical principles of these devices are somewhat complicated and the results of the analysis should be of considerable assistance to manufacturers. Some of the results of this work have been incorporated in a specification of the Standards Association of Australia on retroreflectors and retroreflecting materials.

(vi) *Optical Properties of Diffusing Media.*—The optical properties of diffusing materials have never been adequately studied theoretically although much of the large amount of theoretical work relating to the diffusion of radiation through solar or stellar atmospheres is applicable to the problem. A study of the phenomenon is in progress and the results may have a number of industrial applications. This work has already led to an improved method for the quantitative measurement of cytochrome in various bacterial suspensions.

(*b*) *Optics.*—(i) *Reflecting Microscopes.*—The study of reflecting microscope designs has been extended from objectives with two or three spherical mirrors to objectives with four. It has been shown that only a very few types of four-mirror objective are possible and that while no improvement in numerical aperture is obtained, improved contrast should result. A typical objective has been designed for construction and testing which should be simpler to produce than a three-mirror model.

(ii) *Definition in Optical Instruments.*—Progress has been made in the development of equipment for the measurement of image definition in telescopes and microscopes. The method involves the measurement of image contrast with an object having a line pattern with a sinusoidal variation in luminance.

(iii) *Choice of Glass for Cemented Doublets.*—Small telescope objectives and also those for low power microscopes are most conveniently made as cemented doublets of two different types of optical glass. Since it is not possible to correct the aberrations adequately for any arbitrarily chosen pair of glasses, it is desirable to be able to choose a suitable pair at the start of the design. Methods for selecting optimum combinations are well known for thin telescope lenses of low aperture; but have now been developed for any aperture, magnification, and residual aberration. It has been shown that the same pair of glasses is suitable for fully corrected telescope objectives of all apertures, and that a few additional glasses suffice for microscope objectives of a large range of magnifications.

(iv) *Meteoric Dust in the Atmosphere.*—The studies of the diffusion of light already mentioned have also been directed to the problem of detecting meteoric dust in the upper atmosphere (*see* Chapter XXVIII., Section 9 (*d*)). Certain small changes in the intensity of solar radiation have been interpreted elsewhere as due to meteoric dust. An analysis of the results strongly suggests that the meteoric dust particles become nuclei for the formation of ice crystals at a height of about 80 kilometres. The concentration and size of the crystals further suggests that they constitute noctilucent clouds such as are also known to be associated with meteor showers (*see* Chapter XXVIII., Section 9 (*d*)).

(*c*) *Solar Physics.*—An account of the Division's work in solar physics will be found under Extra-terrestrial Physics, Chapter XXIX., Section 2.

XXVI. ELECTROTECHNOLOGY.

1. General.

Much electrical work, particularly in electronics, is undertaken in Divisions and Sections as an integral part of research in other fields of investigation, but the Organization's research on electrical measurements and standards and on electrotechnology is carried out within the Division of Electrotechnology, which is part of the National Standards Laboratory (see Chapter XXIII.).

The Organization also collaborates with the Electricity Supply Association of Australia in encouraging electrical research within the Universities through its Electrical Research Board (*see* Section 9 of this Chapter).

Division of Electrotechnology.—The Division is responsible for the maintenance of the Commonwealth standards of measurement of electrical quantities other than the primary electrical standards—the volt and the ohm. It maintains the Commonwealth standard of measurement of frequency in conjunction with the Commonwealth Observatory, Mt. Stromlo, and other standards derived from frequency, resistance, and electro-motive force. The Division undertakes electrical and magnetic measurements on materials, and the calibration of instruments and equipment such as resistors, bridges, potentiometers, capacitors, inductors, indicating instruments, instrument transformers, signal generators, wavemeters, and fluxmeters. Research is being continued to improve and extend the electrical measuring and standards facilities, and on the dielectric properties of insulating materials and the microwave spectra of gases.

2. Direct Current.

(Division of Electrotechnology.)

The special resistor for building up from 1 to 100 ohms has been completed and tested. It consists of eleven 10-ohm resistors permanently connected in series with provision for connecting groups of resistors in parallel or series-parellel. By substitution in a Wheatstone bridge the values of the resistors may be determined in terms of the 1-ohm national standard of resistance and then used in the calibration of 10- and 100-ohm standard resistors. The build-up resistor can also be used as a pair of bridge ratio arms with a nominal ratio of 10:1 that can be established accurately by substitution measurements. Tests have shown that the build-up resistor can be used for the intercomparison of 10- and 100-ohm resistors with a 1-ohm resistor to an accuracy of a few parts in 10^7.

To extend this technique to the calibration of 1,000- and 10,000-ohm resistors a build-up resistor with 1,000-ohm coils is being developed. Experimental coils of a type originally developed at the National Physical Laboratory have been constructed. Tests over several months have shown that the resistance of these coils is very stable, the initial drift being about 1 part in 10^6 per month. These tests will be continued to determine the long-term stability of the coils. The coils have been wound with constantan wire, which is considered to be more corrosion-resistant than the more usual manganin.

3. Power Frequency.

(Division of Electrotechnology.)

(*a*) *Voltage Transformer Testing Set.*—In modern commercial practice, voltage transformers are calibrated by comparison with standard transformers using a "testing set". Profiting from the experience gained in calibrating a number of testing sets, the Division has developed a portable testing set with some new features which make it very convenient and accurate to use.

(*b*) *Low Frequency Tuned Amplifiers.*—Bridge methods of electrical measurement have wide application but can be restricted both in the type of bridge and the range of measurement unless a sensitive detector is used. In the past, limitations have been imposed by the lack of sensitivity of the vibration galvanometer normally used as the detector. This limitation has been removed to a large extent by the development within the Division of a number of tuned elecronic detector-amplifiers with power sensitivities approximately one million times greater than those of the best vibration galvanometers. A variety of input transformers enables the amplifiers to be used efficiently with a wide range of bridge impedances.

(*c*) *Ionization in Small Power Transformers.*—It has been found that small air-cooled power transformers often fail in service because their operating voltage is above the ionization onset voltage of the insulation, thus causing rapid deterioration. It has been shown that an effective solution of the problem is to separate the insulation into layers by means of metal foils and thus considerably increase the ionization onset voltage for a given overall thickness of insulation.

(*d*) *Miscellaneous Instruments.* — Miscellaneous items of new equipment developed during the year include a 3 kW., 150 c/s. harmonic generator operated from the 50 c/s. mains, a peak-reading voltmeter with a long time constant, and a compact 10,000 pF 3-terminal sealed nitrogen-filled capacitor.

4. Audio and Radio Frequency.

(Division of Electrotechnology.)

(*a*) *Stable Capacitors.*—The day-to-day stability of the best fixed air capacitors of conventional design when maintained under laboratory conditions and corrected to a fixed reference temperature, is seldom better than a few parts in 10^5 and under unfavourable atmospheric conditions may be worse than 1 in 10^4 This is in marked contrast with the behaviour of the best resistance and inductance standards, where a stability of about 1 in 10^6 is to be expected under the same conditions. The inferior performance of pacitors is found to arise from a number of con- ibutory causes, most of which can be eliminated or at ast controlled by suitable design. Several experi- ental capacitors have been constructed in which all dundant mechanical constraints have been removed om the electrode structure. The dielectric medium as been stabilized by sealing the capacitors in an mosphere of dry nitrogen. The relative values of vo such capacitors have remained within 1 part in 0^6 of each other for a year.

(b) *An Absolute Standard of Capacitance.*—Various ossible forms of capacitor suitable for calculation rom precise metrological measurements have been onsidered. Detailed investigations of the effects of nall mechanical departures from geometrical perfec- on have been made by the use of models with xaggerated errors.

(c) *Impedance Measurements.*—The determination f the ohm based on the calculation of capacitance volves the use of an alternating current bridge ethod to measure resistance in terms of capacitance nd frequency. To compare the value of resistance obtained with direct current standards it is necessary have a transfer resistor whose alternating current nd direct current resistances are the same or for hich the difference can be calculated. Two 4-terminal 00-ohm resistors have been constructed for which the ransfer error should be less than 1 in 10^7 for frequencies p to 1,000 c/s.

Considerable progress has been made in the design f small 3-terminal capacitors and the equipment for eir precise measurement. Switched decade dials are referred for measuring equipment and are obtained y switching a single capacitor per dial to different ps on a special ratio transformer. The same rinciple has been used in the construction of a -terminal capacitor which has six decade dials, a tal capacitance of 1 pF, and a subdivision of 1μpF.

(d) *Frequency Measurement.* — The electronic ircuits of the oscillators comprising the national andard of frequency have been improved to the xtent that the major remaining limitation on erformance is the stability of the quartz crystals emselves. A special oscillator circuit has been eveloped to limit the crystal current to a very low able value and a special oven control circuit has been eveloped to maintain the crystal temperature constant nd independent of ambient variations.

In the range above 100 Mc/s., frequency measuring quipment has been developed for all frequencies for hich waveguide equipment is available.

(e) *Noise Generators.*—Fundamental investigations ave been continued on noise generators, which are sed at high radio frequencies for determining the bsolute sensitivity of radio receivers. Equipment has een completed for calibrating noise generators in rms of the noise power output from a black-body adiator of low, but known, uniform temperature. his equipment has been used for calibrating a high ntensity substandard noise generator using an argon- lled discharge tube.

(f) *Microwave Spectroscopy.*—Numerous tests on ell-known spectra have established that the sensitivity nd resolving power of the Division's spectroscope are ow comparable with the best results reported by other orkers. During these tests new features of the icrowave spectra of carbonyl sulphide and of sulphur ioxide have been observed, and are being examined rther. A preliminary examination of the spectrum phenol has been made. Additional developmental ork is being carried out on the spectroscope to nprove the instrumentation, and broaden the available equency range of operation in order to examine a ider class of spectra.

(g) *Millimetre Wavelengths.*—Apparatus for the generation and detection of radio energy at wavelengths between 6 and 7 mm. has been put into operation, in addition to that at about 8 mm. reported previously.

5. MAGNETIC MEASUREMENTS.

(Division of Electrotechnology.)

There has been a considerable increase in the demand for magnetic tests on materials and this has been met with the aid of new measuring instruments and techniques described in previous reports. The development of a medium field strength meter (1-3,000 oersteds) has reached an advanced stage.

6. DIELECTRIC INVESTIGATIONS.

(Division of Electrotechnology.)

Work on the relationship between the chemical and physical structure of pure compounds and their dielectric properties has continued. While the bulk of the work has been with organic compounds the properties of some inorganic compounds of a complex nature are being examined in collaboration with the Division of Industrial Chemistry.

(a) *Theoretical Work.*—Theoretical investigation of dielectric breakdown is continuing. A greater understanding of the physical picture of the breakdown of ionic crystals has resulted from recent work on the stability of electronic currents at high field strengths in such substances. It is believed that the ideas developed may be applicable to other solid dielectrics, and even to liquids. However, the exact mechanism of avalanche formation and decay is not yet fully understood.

The influence of electrode material as a factor determining the apparent breakdown strength of a solid or liquid has also been investigated. This topic seems to be of some importance for non-polar liquids (such as transformer oil) as their breakdown strength varies greatly over different measuring conditions.

(b) *Occlusion Compounds.*—Dielectric measurements have been made on a wide range of urea occlusion compounds. The absorption is very large and occurs mainly at very high frequencies. Measurement of the dielectric loss at a particular frequency or of the low-frequency dielectric constant is probably the most convenient method of determining the concentration of long-chain material actually present in the urea crystal structure. In association with the Division of Industrial Chemistry the occlusion compounds of certain clays were investigated but conducting impurities masked any dielectric absorption effects.

(c) *Hydroxy-compounds.*—In order to elucidate further the relationship between the dielectric properties and hydrogen-bonding, an investigation has been made of di-*ortho*-substituted phenols in which the hydroxyl group is capable of hydrogen-bonding alternately to one or other of the two *ortho*-substituents. The dielectric absorption was much less than that obtained with long-chain alcohols where extensive intermolecular hydrogen-bonding is known to occur.

(d) *Aliphatic Esters.*—It has been established that some long-chain compounds in which the dipole is at one end of the molecule possess dielectric absorption in the microwave region. Further information about the machanism of this absorption is being obtained by measurements on a number of aliphatic esters in which the dipole group is at varying distances from the end of the long-chain compounds. From measurements at lower radio frequencies complete quantitative information has also been obtained about the energy barriers opposing rotation of the molecule and about the energy differences between the different positions of equilibrium.

It has been discovered that one particular compound, butyl stearate, remains in the metastable waxy phase (so-called α-phase) for much longer periods than is usual and that it undergoes reversible phase changes while still preserving its waxy translucent appearance.

(*e*) *X-ray Crystallography.*—The study of the low-temperature form of the secondary alcohol 14-heptacosanol has been continued and extended to material obtained from the melt for both this compound and 10-nonadecanol. Preliminary results indicate that the two methods of preparation give different crystal structures, some indications of disorder being obtained from that formed at high temperatures.

7. Special Instruments.

(Division of Electrotechnology.)

Measurement of Temperature and Salinity of Sea-water.—A portable bridge for the measurement of temperature and salinity of estuarine waters to a depth of 60 feet has been made for the Division of Fisheries. The bridge is direct-reading in both temperature and salinity.

Work is progressing on the design of an instrument to record the same two quantities in the ocean to a depth of 3,000 feet.

8. Vacuum Electronics.

(Division of Electrotechnology.)

The Division's work on electronic computation is described in Chapter XXX., Section 4.

9. Electrical Research Board.

(Division of Electrotechnology.)

The general objective of the Electrical Research Board is to foster fundamental electrical research in Universities and the training of graduates in research methods. Grants are made for projects suggested by the Universities.

The Board is representative of the Electricity Supply Association of Australia, the Universities, and the Organization. Financial support from member organizations of the Electricity Supply Association has enabled the Board to support investigations in most of the Universities of Australia.

Investigations on the stability of power supply systems are being continued in the University of Adelaide with simulating networks and in the University of Melbourne by a model machine technique. Transients are being studied in the University of Tasmania. In the University of Queensland the impulse generator has been assembled and operated at reduced voltage and the occurrence of lightning is being investigated. The fundamental properties of semiconductors are being studied in the University of Sydney, where also a new project has been commenced on electronic counters and amplifiers of extremely short time resolution. Studies of electric arcs in the University of New England are being continued by investigation of the loss of electrode material from hot spots. In the University of Western Australia the project on the application of single-phase motors on badly regulated lines is being continued, and assistance is being given with the construction of a vacuum spectograph for studying the X-ray emission and absorption spectra of solids.

XXVII. RADIOPHYSICS.

1. General.

The techniques of radio and particularly its more recent offshoot, radar, have found employment in an ever-widening field of both scientific and industrial application. The use of pulse methods and the exploitation of very much higher frequencies than was possible a decade ago have provided scientists with new research tools of surprising versatility and power. The Division of Radiophysics is organized to carry out investigations in fields in which modern radio techniques have particular application. Chief among these are fundamental researches in cloud and rain physics and radio astronomy—fields in which it has already established an international reputation. The Division is also concerned with the study of physical properties of semiconductors, and especially the devices known as "transistors" which are initiating a major revolution in electronic techniques; with the development of radio aids to navigation; and with high-speed computation by electronic means.

The Organization also undertakes research into the propagation of radio waves. This is done in collaboration with the Services, the Postmaster-General's Department, and the universities, under the direction of the Radio Research Board. Liaison between the various bodies carrying out research in the radio field and those who make use of the results of this research is facilitated by a Consultative Committee on Radio Research.

The work of the Division of Radiophysics is outlined in Sections 2, 3, and 7 (*b*) of this Chapter and in Chapter XXVIII., Section 9; Chapter XXIX., Section 3; and Chapter XXX., Section 3. That of the Radio Research Board is described in Section 7 (*a*) of this Chapter.

Division of Radiophysics.—The Division is predominantly engaged in fundamental research in two fields, rain and cloud physics and radio astronomy. Developmental work dealing with radio aids to navigation and with electronic computing is also included in its programme; while more recent additions have been investigations on the physics of semi-conductors and transistors, and their applications in electronic circuitry. For fuller details of the work of the Division than is given in this Report, the published papers listed in Chapter XXIV. should be consulted.

Radio Research Board.—The Board maintains a small permanent staff and also fosters approved projects in any universities where the opportunity and need for assistance exist. The Board's studies contribute useful knowledge in two ways: (i) by studies of radio propagation and all factors affecting radio communication paths; (ii) by study of air movements in the very high regions of the upper atmosphere by radio means.

These two subjects are closely interlinked and studies of both can best proceed simultaneously. The work of the Board during the past year has contributed materially to the knowledge of fundamental conditions and processes involved. New lines of attack are constantly being devised and improved equipment deployed in the investigations.

The Board's officers work in close co-operation with officers of the Ionospheric Prediction Service of the Department of the Interior, so that any new information on propagation may be utilized by them as rapidly as possible.

Information on upper air movements is of great current interest from both scientific and defence aspects. The Australian Academy of Science has set up an Upper Air Committee to co-ordinate this work within Australia and with similar bodies overseas. The Board's Chief Scientific Officer is Chairman of this Committee. The work already done by the Board provides a very good basis from which such investigations may be expanded.

2. RADIO AIDS TO NAVIGATION.

(Division of Radiophysics.)

During the past year the principal investigations ve been concerned with a proposed method of vigating long-range aircraft by measurement of tance from the terminal points of the path; no sting systems meet all the operational requirements modern commercial aircraft. Some experiments ve also been conducted on the determination of ffic conditions on roads.

(a) *Long-range Navigation by Distance Measurent.*—In the method proposed, synchronized pulse nsmitters are located at each end of the flight path l the distance of the aircraft from one terminal determined by comparing the arrival times of the o pulses at the aircraft. The distances measured e such that propagation via the ionosphere is olved; hence a knowledge of the characteristics of ique-incidence propagation over long distances is essential pre-requisite.

Analysis of the results of propagation conditions er the Camden-Townsville path set up last year has own that the system should be useful for flights up 1,400 miles long, using the first order reflection m the E layer. For flights over the sea two radio quency channels should provide coverage over most the 24 hours.

To test the conclusions of the system analysis and provide information on the problems of ground tion and aircraft instrumentation, a transmitting tion has been set up on a coastal site near Sydney, provide, with the Division's existing station at wnsville, an experimental model of the system.

(b) *Measurement of Traffic Conditions on Roads.*—mote methods of surveying traffic conditions on ds have been investigated. These include a device king use of the radio-Doppler effect for measuring icle speed, and a simple optical method recording otographically the speed and distribution of hway traffic at night.

3. PHYSICS OF SEMI-CONDUCTORS.

(Division of Radiophysics.)

Very considerable effort has been devoted in the st few years, particularly in the United States, to e development of devices based on the peculiar operties of materials classed as semi-conductors, which e equivalent, and in important respects superior performance, to radio valves. The introduction of ese "transistors" is initiating a major revolution electronic techniques. The Division has therefore up a small section to study the basic physical ocesses governing the action of transistors, and the ecial circuit techniques required to make the best e of their special properties.

(a) *Fundamental Investigations.*—Equipment has en built up for the purification of semi-conducting aterials, for the growth of single crystals of rmanium having the necessary properties, and for oducing specimens of the required size and shape. nall-scale production of both junction and pointntact transistors, using germanium as the seminducting element, is under way. Fundamental vestigations of electronic noise in semi-conductors e in progress, including measurements down to liquid trogen temperatures.

(b) *Transistor Circuit Development.*—Basic test uipment has been designed and is under construction, cluding a characteristic-curve tracer, a bridge for easuring small-signal parameters, a frequencysponse tester, and noise measuring apparatus. ending the ready availability in quantity of junction pe transistors, circuit development has been restricted the construction of a few simple units.

4. MATHEMATICAL COMPUTATION.

(Division of Radiophysics.)

The Division's work on mathematical computation is reported in Chapter XXX., Section 3.

5. CLOUD AND RAIN PHYSICS.

(Division of Radiophysics.)

The Division's work on cloud and rain physics is reported in Chapter XXVIII., Section 9.

6. RADIO ASTRONOMY.

(Division of Radiophysics.)

The Division's work on radio astronomy is reported in Chapter XXIX., Section 3.

7. THE IONOSPHERE.

All long-distance radio propagation takes place through the ionosphere. The normal ionosphere is maintained in its ionized condition by radiation from the sun and therefore shows daily and seasonal variations. These are now reasonably well known for most regions of the earth. Less is known about the abnormalities, such as ionospheric storms, which disrupt radio communications from time to time, particularly when sunspots are active on the visible solar disk. The most common method used for studying the properties of the ionosphere involves reflection of radio signals. An alternative method consists of making use of radiation from cosmic radio sources and determining the effect produced by the ionosphere on this radiation as it passes through the earth's atmosphere. These effects may change with time either slowly or rapidly.

(a) *Investigations by the Radio Research Board.*—(i) *Morphology and Theory of Ionospheric Processes.*—During the past year, attention has been concentrated on studies of the anomalous F_2 region, the conductivity of the ionosphere, storm morphology in the ionosphere, and ionization movements in the ionosphere. The work on the F_2 region and the conductivity of the ionosphere has provided solutions to several major problems of the ionosphere which have hitherto defied satisfactory explanation. Work on storm morphology in the ionosphere appears likely to have an important application to the alleviation of the disruption of overseas communications which now occurs during ionospheric storms. Sufficient is now known of the course of these storms (over three days) to enable specific remedial measures to be taken. In some of this work valuable assistance has been received from the Ionospheric Prediction Service of the Department of the Interior.

The work of these sections is based mainly on information from the world-wide network of ionospheric observing stations. Work on ionization movements in the ionosphere is closely linked with the observational work described in (ii) below.

(ii) *Upper Air Movements at Ionospheric Heights.*—Movements in the high atmosphere are assuming increasing importance, both directly because of their effects on aircraft and projectiles and indirectly because of their relation to meteorological conditions in the lower atmosphere. Workers assisted by the Board are attacking this problem in three different ways. Work of the Board's permanent staff at Sydney is based on observations of movements of disturbances as they pass over three spaced observing points some 40 miles apart; these observations have so far been mainly by day. Another group at the University of Queensland has been carrying out allied measurements using a rather similar technique, but mainly at night. A third system using observations of meteor trials has been developed at the University of Adelaide. These three centres are contributing to the general picture without overlapping.

Parallel with the observational work an intense theoretical study is maintained, to interpret the results and guide further experiments.

(*b*) *Investigations of the Division of Radiophysics.*—The Division is not directly engaged in ionospheric investigations as such, but several aspects of the work are providing information which has a direct bearing on radio propagation problems. Radio waves of solar and cosmic origin are absorbed in varying degrees in their passage through the ionosphere and these variations may be used to provide information on ionospheric absorption. Useful data on oblique-incidence propagation are also being obtained as a result of tests that were necessary in connexion with the development of a long-range navigational system described above.

(i) *Scintillation of Discrete Sources.*—The twinkling of radio stars is known to arise within the earth's atmosphere. Analysis of a long series of observations on four discrete radio sources has shown that the amplitude of the scintillations varies both seasonally, with minima near the equinoxes, and diurnally, with minima near dawn and sunset. The amplitude of the scintillations correlated well with the occurrence of sporadic E but not with "spread F" conditions. These results are at variance with those derived in the northern hemisphere and suggest that both E and F regions may contribute to the scintillation.

The spectral characteristics of the scintillations are being studied by means of the radio-frequency specrograph, over the range 40-240 Mc/s. One interesting result already obtained is that variations with frequency are often regular, and not random as has generally been assumed.

(ii) *Measurement of Ionospheric Absorption.*—A systematic study of the small variations in intensity of cosmic radio waves observed at a frequency of 18.3 Mc/s. shows that these are associated with changes in the ionosphere. Two separate componets of the absorption can be distinguished, one due to the D region and the other to the F region. This method yields the absorption due to the whole depth of the ionosphere, and hence its use, in conjunction with those used in normal ionospheric studies (which refer only to the lower regions), is likely to yield useful information concerning the upper, and otherwise inaccessible, F region.

(iii) *Effects of Solar Flares.*—Observations of the intensity of solar radio waves have been shown to provide a simple but particularly sensitive method for detecting the sudden ionospheric disturbances (causing fade-outs) which are associated with solar flares. A particular advantage gained is that the variations in absorption can be followed in detail throughout the course of the disturbance; in contrast with normal methods, where no record is obtained during the severe phases.

(iv) *Oblique-incidence Propagation.*—Regular pulse transmissions between Camden and Townsville have been carried out at a frequency of 9.8 Mc/s. to provide propagation information relevant to the long-term navigation aid being investigated by the Division. The first order E reflection has shown consistent delay times in agreement with predictions based on vertical-incidence data from Brisbane. The equipment has been modified to provide photographic records of the amplitude of the received pulses to serve as a basis for a study of diurnal and seasonal variations of slow fading and of normal interruptions to the circuit over an extended period.

XXVIII. ATMOSPHERIC PHYSICS.

1. General.

The Organization is undertaking a number of basic studies of the physics of the atmosphere with the object of attaining a more fundamental understanding of the weather and the processes which control it. Meteorology is a public utility on which almost every phase of the community life depends in some way. It already provides a wide range of services to the public, but these can only prosper and improve against a background of basic research into the many problems yet unsolved. Furthermore, Australian scientists have played a leading part in a series of experiments in rain physics, which could lead to results of great interest for a continent such as Australia which lacks adequate water supplies over wide areas.

The Organization's major investigations in the field of meteorology are undertaken by the Section of Meteorological Physics at Aspendale, Victoria. This work includes studies on dynamical meteorology, general circulation, heat balance, and micrometeorology, including its application to frost prevention (*see* Sections 2-7 of this Chapter). The Division of Radiophysics, on account of its access to the radar techniques employed in this work, is engaged in a careful scientific study of the processes in nature which give rise to cloud and rain, and of possible methods of stimulating rainfall by artificial means (*see* Section 9 of this Chapter). The Division of Physics at the National Standards Laboratory has also undertaken laboratory investigations, in collaboration with the Division of Radiophysics, on some aspects of rain-forming processes (*see* Section 8 of this Chapter).

Section of Meteorological Physics.—The Section aims at attaining a more fundamental understanding of the weather and of the physical processes which control it. In addition to that part of the research programme with bears directly on the Australian's needs and problems, the international aspect of meteorological research are given constant attention. The Officer-in-charge is Secretary of the National Committee on Meteorology, which reports to the International Meteorological Association. A meeting of the Standing Committee for Meteorology of the Pacific Science Association was attended by an officer of the Section in November; and during the current year a visit was received from the delegates to the South-West Pacific Regional Commission of the World Meteorological Organization. The Officer-in-charge is also a member of the Working Group on Minoclimatology of the World Meteorological Organization.

The Section moved to its new head-quarters at Aspendale in November, 1953.

2. General Circulation.

(Section of Meteorological Physics.)

To reach a better understanding of seasonal abnormalities and the causes and controls of climate it becomes necessary to study the mechanism of the general circulation of the atmosphere. This involves evaluation of the large-scale transport of heat, water vapour, and momentum from world-wide measurements from balloons ascending to 50,000 feet and higher.

This is an international problem and only relatively slow progress can be expected. During the year a paper has been published summarizing the results of Australian work to date. Apart from the detailed results there emerges a clear indication of the need for greater effort to obtain more regular high-reaching measurements at existing world stations, particularly on occasion of strong upper ("jet stream") winds.

3. DYNAMIC METEOROLOGY.

(Section of Meteorological Physics.)

(a) *Large-scale Systems.*—The study of the dryonsoonal circulation which predominates over the est and north-west of Australia has been continued, nd extended to include relations between the largecale distribution of pressure and rainfall over the ontinent and in the trade wind belt. The basic object f this work is to assess the effect of continual heating n the circulation in the region. Data covering ten ears' observations have been extracted and are being ollated, with promise of interesting results. In articular some of the large-scale features, seen epeatedly in the surface pressure charts, appear due o the action of topography on easterly winds. This ill be tested further. Some qualitative rules useful or short-term forecasting may also emerge from this ork.

Sea breezes are examples of diurnal wind variations rising from differential heating at the coastline, but iurnal wind variations to considerable heights have een detected in regions far inland. A survey of pper winds has shown the continent-wide extent of ese influences. Their share in sustaining the seasonal urface circulation is being explored.

A detailed analysis of upper winds from Kalgoorlie, Vestern Australia, and Cloncurry, Queensland, ndicates that the diurnal oscillation in these regions s largely due to a vertical momentum transfer varying ith the intensity of convection and thus with time f day. A quantitative dynamical study of this effect hould soon be completed.

Examinations are being made of discontinuities in emperature, moisture, and wind associated with cold ronts in southern Australia. One investigation is ased on radio soundings for four winter seasons at erth and Kalgoorlie, and a tentative classification of ronts in this region has been evolved. It is planned o explore its relation to the subsequent history of he fronts and to the large-scale flow patterns.

Synoptic aspects of the processes accompanying brupt falls of temperature in summer ("cool hanges") form another part of this programme. ssistance has been given by the Commonwealth leteorological Branch and a number of Victorian tate authorities in obtaining special observations equired for the more detailed study of such changes ffecting Victoria and southern New South Wales. ollowing a trial last summer it is planned to resume he co-operative part of the work next spring.

(b) *Convection.*—Theoretical work has led to the dentification of five modes (three principal, two ransitional) of convective motion, depending on the emperature condition of the environment and the size f the convective element. In particular, large upward elocities can be developed only when the air is tatistically unstable and the "bubble" exceeds a ertain critical size. Given the rate of mixing, the emperature and velocity of the bubble can be calcuated in any known environment.

This problem is of importance in vertical heat ransfer in the atmosphere and in rain and cloud hysics. Substantial rain requires substantial rates f uplift for its initiation and continuance, and the nain limiting factor in rainfall is most probably the xtent of vertical motion within the individual cloud.

Theoretical and experimental studies have been egun on continuing convection from artificial sources, vhich has bearings on frost protection and atmosphere ollution.

4. MICROMETEOROLOGY.

(Section of Meteorological Physics.)

The major effort in micrometeorology has continued o be an intensive investigation of the transfer of heat nd water vapour from the ground surface to the atmosphere and also of the frictonal influence of the ground on the wind. These fundamental studies have been framed, not only to give much-needed knowledge of the processes by which atmospheric air-masses undergo modification in travelling over land and sea, but also to provide means for a more thorough study of evaporation from natural land surfaces and from crops than has been possible with previous largely empirical methods.

The specially developed equipment in use at the Edithvale (Victoria) experimental station provides the observational material for these measurements of turbulent transport and also yields a wealth of data for studies of the structure of atmospheric turbulent motion—studies of importance in relation to the diffusion of matter (smoke, factory chimney effluents, pollen, &c.) in the lower atmosphere. The equipment has been extended and improved in the last year and now gives synchronous records of the turbulent structure of wind, temperature, and humidity at two separate points.

Analysis of the records obtained this year and last has been pressed forward to the full capacity of the special machine analyser built for this work. It is found that these techniques enable evaporation to be measured over short periods of time (10-20 min.) with an accuracy far beyond that which seems feasible with the gravimetric methods under development elsewhere. A further important advantage is that no disturbance of a crop-bearing surface is entailed. It has also been established beyond doubt that heat is conveyed to the atmosphere by a distinctly different mechanism than operates for momentum or water vapour, a hitherto very controversial matter and one having important implications in the study of evaporation.

A supplementary study of the very fine structure of atmospheric turbulence using cathode-ray oscillograph techniques is well advanced.

For any wide practical application of the above technique to specific agricultural evaporation problems it is desired to devise an instrument to give direct readings of evaporation and so eliminate the formidable amount of computation at present required. Preliminary designs for such an instrument are well on the way but, although the principle is clear, a considerable amount of electronic engineering work remains to be done and it will be some time before an instrument suitable for operators who are not trained physicists is available. An extension of this method should also facilitate investigation of heating and frictional effects.

An observational study of wind gusts in the lowest 500 feet has been completed and briefly reported to the Postmaster-General's Department, which requires the information in connexion with the design of tall radio masts.

Apparatus has been designed and built for several agricultural research workers, mainly for fine-structure recording of temperature and humidity in connexion with such problems as: micro-environment studies of growing pasture plants and also of crops under trial in the Northern Territory—cotton, peanuts, &c.; humidity structure studies in connexion with mildew diseases of grape-vines; ponding of cold air in valleys in relation to the tree line; temperature inversion survey in Queensland pineapple districts in relation to the frost problem; temperature influence on the life cycle of intestinal parasites of sheep. Radiation equipment has been repaired and recalibrated for several research stations, and advice and assistance given with observational programmes.

On the theoretical side, the energy changes involved in mixing an inversion layer have been investigated with reference to frost prevention and it is found that the energy required to maintain mixing in a

100-ft. layer is only a small fraction of that supplied by the usual design of frost fan. Considerable improvement in frost fan performance is therefore not excluded.

5. Frost Prevention.

(Section of Meteorological Physics.)

During the winter of 1953, frost prevention trials in citrus were continued at Griffith, New South Wales, using the 12-ft. diameter airscrew on the low-powered wind machine (*see* Chapter IV., Section 3). Trials were conducted at increasing angles of tilt of the blades until they were nearly vertical. The best performance was obtained with the air blast directed at about 15° below the horizontal. Data collected by the Irrigation Research Station in trials with an experimental American-type machine were analysed, and also showed optimum performance at about the same tilt. An operational test was made of a small number of return-stack orchard heaters, now manufactured in Melbourne, in conjunction with the small wind machine.

Further experiments, in co-operation with the Queensland Department of Agriculture, were conducted on the Pineapple Research Farm of the Committee of Direction of Fruit Marketing. The disappointing performance of the small wind machine, suggested in earlier trials, was confirmed; but the reason is now believed to lie, not in anomalous meteorological conditions, but in the requirement of an open-type crop for a type of air blast different from that best suited to citrus. Considerable data were also collected with various concentrations of small lard-pail type oil heaters spread over 1 acre, both on their own and reinforced by the wind machine.

A wind machine is now available commercially. A preliminary test in a vineyard in South Australia in the spring was encouraging, and more detailed trials are planned for the coming winter.

Continuing laboratory work on frost alarms to improve reliability has led to modification and field trials of two commercial thermostats. A study is now being undertaken of the temperature differences under various conditions between the instruments, foliage, fruit, &c., and the air. Bad siting and exposure can result in mistimed warnings from an otherwise reliable instrument.

6. Radio Meteorology.

(Section of Meteorological Physics.)

The Section has done no work in this field during the current year.

7. Other Investigations.

(Section of Meteorological Physics.)

(*a*) *Ozone Investigation.*—World-wide measurements of the ozone content of the atmosphere have been made for some years under international auspices, but very few observations have so far been made in Australia. Three instruments for this purpose are now being adjusted and a measuring network will be set up in southern Australia. The measurements should provide information on the general circulation, and an index of developments at high levels of possible value in routine analysis and forecasting.

(*b*) *Sea Surface Temperature Measurement.*—A test of the accuracy of the accepted dip bucket technique for measuring the true surface temperature at sea has been completed. Temperatures measured by bucket in Port Phillip Bay, on clear days of light wind when discrepancies might be expected, averaged about ¼° C. higher than surface temperatures derived from simultaneous measurements of emitted radiation.

(*c*) *Maximum Rate of Rainfall.*—Knowledge of upper limits to the rainfall within a stated period are required for various purposes of water use, conservation, and flood control. Since rainfall is not normally measured for periods between 1 and 24 hours, the limits in this range have to be interpolated. An examination of world-wide data, including the Australian station, has given evidence of one or two breaks in the intensity-duration relationship in this range. The attention of hydrologists has been drawn to this result and its implications.

(*d*) *Rainfall and Meteoric Dust.*—An appraisal was made of the influence of meteoric dust on rainfall, with the conclusion that on present knowledge any significant influence was improbable.

8. Precipitation.

(Division of Physics.)

By combining experimental results on the rate of sublimation of carbon dioxide in a moving air stream with others on ice crystal formation by the passage of carbon dioxide pellets through supercooled fogs, it has been shown that the number of ice crystals produced by the sublimation of a given mass of carbon dioxide increases linearly with decreasing temperature of the supercooled fog.

These results have been applied to the calculation of the ice crystal formation to be expected by seeding typical clouds with carbon dioxide pellets. Measurements, incidental to this calculation, to determine the terminal velocities of carbon dioxide pellets give results in good agreement with theory.

Some further work has been done on the collision cross-section of water drops with mist droplets.

9. Cloud and Rain Physics.

(Division of Radiophysics.)

Two factors, more than any others, have been responsible for substantial advances in recent years in our understanding of the physical processes which give rise to the formation of cloud and rain. The first is the availability of powerful microwave radar techniques, and the second a more than usually urgent need for such an understanding because of the possibility that has been revealed of stimulating rain by artificial means. The Division has in many respects pioneered a thorough scientific investigation of as many of the factors involved as are susceptible to measurement, and has in the process developed new techniques and new instruments which are now finding application in other countries. Much of the work is performed in specially equipped aircraft, work which would not have been possible without the active co-operation of the Royal Australian Air Force.

(*a*) *Cloud Formation.*—There is a limit to the amount of water vapour that air can hold and this is predominantly a function of its temperature. When this limit is reached—usually in nature by cooling of the air mass—" saturation " occurs. In pure air, however, the excess water does not condense out as water droplets until still lower temperatures are reached. Cloud and fog droplets need some type of nuclei upon which to form. Such nuclei are usually abundant in nature, but a knowledge of their constitution, behaviour, and distribution is obviously basic to an understanding of cloud processes. They are of two distinct types:

(i) *Condensation Nuclei.*—These give rise to cloud and fog. They may vary in number from hundreds per cubic centimetre over the sea to hundreds of thousands per cubic centimetre in smoky industrial areas. Samples of these have been collected from aircraft, using oil-covered slides or light frames across which spider webs are stretched, and examined and identified in the laboratory. Air which has travelled for much of its path over sea is found to contain relatively few nuclei but these are of large size. They are hygroscopic and composed of sea salt crystals, formed by the bursting of small bubbles at the sea surface, and almost certainly play an important part in determining whether rain subsequently follows. Air which is of continental origin usually contains numerous minute nuclei which consist of dust and the products of combustion of coal, wood, and oil. Extensive flights over south-eastern Australia have shown that the predominant nuclei are small sea salt crystals which may be transported hundreds of miles inland by wind movements.

(ii) *Freezing Nuclei.*—Just as supersaturation of air is common, so is supercooling of cloud droplets; that is, they do not freeze until temperatures well below 0° C. are attained. The presence of supercooled water droplets constitutes a serious hazard to aircraft, since it can lead to icing-up of the control surfaces. In pure air, cloud droplets do not freeze spontaneously until a temperature of —15° C. or colder is reached. However, freezing can occur at much warmer temperatures if certain nuclei known as "freezing nuclei" are present. The freezing of some of the droplets in a cloud is an essential prerequisite for formation of rain from such freezing clouds by the Bergeron process. While certain natural nuclei having this property obviously exist, there are certain other substances—silver iodide, for example—which behave in the same way. Investigations are therefore in progress to determine the nature and distribution of natural freezing nuclei, and also to study the effectiveness of substances which will serve as "artificial" nuclei equally well.

Natural Freezing Nuclei: These are studied by admitting a sample of the supercooled cloud droplets to a "cold box" carried in an aircraft. The cold box is then further cooled and the temperature determined at which freezing of some of the droplets occurs, these having a distinctive appearance when observed by reflected light. Surveys are being made of the number and distribution of natural freezing nuclei in the upper air. One interesting outcome of this has led to the hypothesis that an important source of these nuclei is the dispersal of meteors in the earth's outer atmosphere.

Artificial Freezing Nuclei: The feasibility of rain production by artificial means clearly depends on the availability of substances to take the place of natural nuclei, when these are absent, and on a clear understanding of how they function. The first artificial freezing nucleus to be extensively tried was silver iodide, but varied and contradictory claims have been made for its effectiveness. Previous inconsistencies have now been resolved as a result of work which shows that the effective life of silver iodide crystals is critically dependent upon temperature and pressure, and is negligible unless they are released at sufficiently low temperatures.

(*b*) *Cloud Properties.*—Once a cloud has been formed, the major factors which determine its subsequent behaviour, and in particular whether rain ensues, are the size distribution of the droplets and the amount of liquid water present at various levels, the cloud temperature, and the air movement and velocity. Observations of these have been continued from aircraft as opportunities permitted.

(i) *Cloud Droplets Spectra.*—Further observations with the cloud droplet sampler, in which rods coated with magnesium oxide are exposed from aircraft, have confirmed that in convective cloud the droplets increase in size and decrease in number with height above the cloud base. An essential step in the determination is the interpretation of the size of a hole in the oxide film in terms of that of the droplet which caused it. A calibration of the method has been undertaken and suggests that the method is of doubtful value with large drops. An alternative sampling surface is being developed, and also a droplet sampler for large drops, in the form of a special tank carried on the aircraft wing.

(ii) *Cloud Water Content.*—From the results so far obtained a survey has been made of the average way in which water content varies with horizontal and vertical position in a cloud. Current theories of cloud formation tend to account for the observed deficiency of water content at any hight above cloud base (over that predicted on a basis of simple adiabatic lifting) as being due to the horizontal entrainment and mixing of drier air from the environment. Results of measurements to date give no support to this theory and imply that present ideas need considerable modification.

(iii) *Air Movement and Velocity.*—Experiments are being continued to determine air movements in the vicinity of clouds, by following with radar the motion of bundles of strips of light metal foil dispersed into the air from aircraft. This has involved increasing the precision of the ground radar by the addition of a second aerial system capable of producing a very narrow beam in the vertical plane. Preliminary measurements have also been made by means of radar systems installed in the aircraft itself.

(*c*) *Rain.*—The known mechanisms in nature which lead to precipitation are the freezing of some of the droplets in a supercooled cloud (the Bergeron process) and the coalescence of smaller droplets, the process responsible for rain from "warm" clouds. An especially interesting outcome of the year's work has been the indication that dust of meteoritic origin has an important influence on rainfall.

(i) *Salinity of Rain.*—Coalescence is initiated by the presence of large droplets, for example, such as can be formed by condensation onto large sea salt nuclei. The salinity of raindrops formed in this way should be a function of their size, and a knowledge of the relationship between raindrop size and salt content should provide important information about the way in which the drops formed and grew.

Accordingly experiments to determine these quantities have been commenced. The raindrop spectrograph developed by the Division in 1951 is used to collect and separate the raindrops into appropriate size ranges, and a flame spectrometer to determine the salt content of each. Initial experiments were made in Sydney and on the Blue Mountains and, through the generosity of the Rockefeller Foundation of New York in making 2,500 dollars available, are being continued for a short period in the Hawaiian Islands, where conditions for the formation of warm rain occur very much more frequently than they do in south-eastern Australia.

(ii) *Laboratory Investigations of Coalescence.*—The coalescence of water drops of diameter 90 μ and upwards has been studied experimentally by suspending drops of nearly equal diameter in a current of air in a vertical wind tunnel. The interesting and significant result has been obtained that uncharged drops of diameter about 150 μ have a "collection efficiency" of 12.5 (about three times greater than expected from theoretical considerations); for charged drops this figure is increased again by a factor of 20.

(iii) *The Effect of Meteoritic Dust on Rainfall.*—Evidence has been found for a possible connexion between rainfall and meteor activity.

During the year, measurements of the distribution of freezing nuclei at heights of 10,000 feet or so disclosed variations which appeared to be unrelated to the origin of air mass, and suggested that the nuclei might possibly be entering the atmosphere from above. A study of the total rainfall received at Sydney, day by day, for the two periods 1859-1901 and 1902-1944 revealed peaks on certain calendar days, and that the dates were closely the same for the two periods. Substantially the same result was obtained by considering similar data for widely separated places in both the northern and southern hemispheres. This provided strong evidence for an extra terrestrial cause. The preferred dates of excess rainfall occur some 30 days after the dates of known meteor streams, suggesting that the agency responsible is the fine meteor dust which enters the earth's atmosphere on the same dates each year, when the orbits of the earth and meteor stream intersect. The interval of 30 days represents the time taken by the small meteoritic particles to settle to the lower regions of the atmosphere, where they apparently serve as freezing nuclei. Their appearance there at times when meteorological conditions were favorable could either intensify rainfall if it were already occurring, or induce it if suitable "natural" freezing nuclei were absent.

If the more detailed analysis at present in progress confirms this hypothesis the implications on current meteorological ideas will be profound, and promising new possibilities with regard to artificial rain-making opened up. As a check on the theory preparations are in hand for systematic measurements of the dust content of the upper atmosphere. Two methods will be used: one direct, by the collection of particles from a high-flying aircraft, and one indirect, from observations of the variation with altitude of the optical scattering of sunlight.

(*d*) *Artificial Rain Formation.*—Attention has been mainly devoted during the past year to a critical examination of the processes previously used for artificial seeding of cloud. Only limited seeding experiments have been carried out.

(i) *Silver Iodide.*—Apart from dry ice, whose effectiveness and method of operation are now well known, the material most used in the past for seeding supercooled cloud has been silver iodide. Extravagant but contradictory claims have been made as to its effectiveness, particularly when released from ground generators. A comprehensive series of experiments has therefore been carried out, both in the field—to study the actual trajectories and effective life of the silver iodide particles after release—and in the laboratory, to determine the factors which influence the effectiveness of the particles as freezing nuclei. Important results which have a direct bearing on future seeding experiments have been obtained, and many of the previous inconsistencies have been resolved.

The field experiments have shown that under the conditions generally prevailing in south-eastern Australia the use of silver iodide generators at ground level is virtually useless, firstly, because it is improbable that the particles will attain the requisite heights in the atmosphere in sufficient quantities, and secondly, if they should happen to do so, they will by that time have lost their ability to act as freezing nuclei. The laboratory experiments have established that the effective life of silver iodide particles is an inverse function of the temperature and the pressure. The number of effective particles generated from a solution of silver iodide in acetone, for example, decays by a factor of 10 in 18 min. at a temperature of + 30° C., but the same decay takes over 4 hr. at a temperature of 0° C.

As a result of this work it is clear that silver iodide should preferably be released from aircraft at the requisite altitude, and that the only situation in which ground generators are likely to be effective are those in which the ground temperature is already low and at the same time an adequate updraught exists (e.g. on the top or slopes of high mountains) to carry the particles rapidly to higher and colder altitudes. Preparations are being made for more extensive trials of both methods.

(ii) *Generation of Freezing Nuclei.*—Laboratory work has been undertaken to arrive at the most efficient way of generating nuclei of the appropriate size and in sufficient quantities. A very satisfactory method, applicable to both small and large aircraft, has been evolved in which a solution of silver iodide in acetone is sprayed into the exhaust stack.

XXIX. EXTRATERRESTRIAL PHYSICS.

1. General.

The new science of radio astronomy—the study of the universe by means of radio waves—is now recognized as an important and integral part of astronomy itself. Apart from providing information which supplements that obtained by optical methods, it has led to entirely now discoveries which could not have been made by the methods of classical astronomy. A more recent development, which is certain to shed light on the origin and structure of galaxies—including that to which the Earth belongs—is the discovery of a radio "spectral line" at a wavelength of 21 cm., due to atomic hydrogen.

Radio astronomy has formed a major part of the research programme of the Division of Radiophysics (*see* Section 3 of this Chapter). Studies of the ionosphere are carried out by the Radio Research Board (*see* Chapter XXVII., Section 7). Work on solar radiation is carried out by the Division of Physics (*see* Section 2 of this Chapter) and cosmic ray investigations at the University of Tasmania (*see* Section 4).

2. Solar Physics.

(Division of Physics.)

(*a*) *Emission of Radiation from Hot Atmospheres.*—The emission of radiation from hot hydrogen atmospheres, of considerable importance in the study of solar phenomena, has been examined for the case of high collision cross sections for transitions between the 2S and 2P substates of hydrogen. More reliable methods of calculating the emission have been developed, and a detailed study made of the value of the albedo for single scattering, on which the radiation intensities very largely depend.

(*b*) *High Altitude Station.*—Plans have been prepared for the establishment of a solar observational station on the Kosciusko plateau at an elevation of approximately 6,000 feet, where the skies are expected to be suitable for coronal observations and for high resolution photography.

(*c*) *Spectroheliograph Observations.*—The Laboratory's spectroheliograph has been used during the past year mainly for testing instrumental devices to be used at the high altitude station which is to be established in the Snowy Mountains away from the poor atmospheric conditions in Sydney.

3. Radio Astronomy.

(Division of Radiophysics.)

Observations of radio-frequency radiation from cosmic sources and from the Sun have been continued, and a number of new and interesting discoveries made. The Division, recognized as one of the leading world centres for research in the new science of radio astronomy, has already pioneered and developed several new observational techniques and a further addition to these has just been completed. The identification of increasing numbers of discrete radio sources has created a demand for pencil beam aerials of high aperture and angular discrimination. In England this hallenge is being met by the construction at Manchester f a steerable parabolic aerial of 250-ft. diameter, stimated to cost £500,000. The Division has evolved method of obtaining an effective pencil beam at very uch lower cost by the use of two long thin arrays in he form of a cross, and an aerial of this form, having rms 1,500 feet long, has been erected near Sydney. It perates at a wavelength of $3\frac{1}{2}$ m. and has a beam width f $\frac{3}{4}$°. This system is extremely efficient at the wavelength for which it is designed, but is not a multirequency system (as is a paraboloid). The need for large parabolic aerial in the southern hemisphere hus still remains and consideration has been given to he feasibility of erecting an instrument of this type n Australia.

(*a*) *Radio Waves from Outside the Solar System.*—i) *Discrete Sources.*—Observations of the discrete adio sources have been continued at a number of frequencies with the object of accurately fixing the positions of those already known, of determining the size nd brightness distribution of the more intense sources, nd of locating new ones. Prominent among the latter as been the discovery of a strong source which is lmost certainly the nucleus of our own Galaxy, while or the first time, one of our nearest external galaxies, he Cloud of Magellan, has also been identified as a adio source.

The size and shape of the strongest sources, Taurus , Virgo A, and Centaurus A, have been studied in etail and found to correspond closely with those of the isible objects (nebulae) with which they have been dentified.

Additional information on the distribution of cosmic oise over the sky at low radio frequencies has been rovided by the completion of two surveys, one at 18.3 nd the other at 9.15 Mc/s.

(ii) *Line Emission from the Galaxy.*—The only line mission from the Galaxy that has so far been detected s that from atomic hydrogen at a frequency of 1420 Mc/s. During the year a careful search for a somewhat analogous deuterium line was carried out in elected regions of the sky, but no radiation at this requency (327.4 Mc/s.) was observed with a receiver apable of recording changes in aerial temperature of s little as 1.5° K.

A survey of the distribution of atomic hydrogen over he Magellanic clouds has been completed. This has rovided much more information about radial velocities vithin the clouds than was previously available from ptical studies, and has shown that each cloud is rotating. Further, the mass of each cloud can be determined rom the knowledge of this rotation, so that the radio bservations provide information on both the mass of ydrogen, and the total mass.

The 1420 Mc/s. radiation from the southern Milky Way is now being studied in detail with a view to elineating the spiral structure of our own Galaxy.

(*b*) *Radio Waves from the Sun.*—Routine observations of the intensity of radio radiation from the Sun have been continued on frequencies of 62, 98, 200, 600, 1,200, 3,000, and 10,000 Mc/s. These are published in he Quarterly Bulletin on Solar Activity of the International Astronomical Union, the Division having accepted the responsibility for editing the solar radio vave section of this Bulletin.

An addition has been made to the Division's 32-element interferometer—the most highly directional erial system yet constructed—by a further sixteen elements in a plane at right angles, so that the Sun's disk can be scanned in two directions at right angles. A series of observations with the original east-west system has confirmed the existence of limb brightening effects, conforming well with theoretical results derived earlier by the Division and apparently conflicting with some earlier English observations. The combined north-south and east-west systems are being used to determine the two-dimensional brightness of the quiet Sun at a wavelength of 21 cm., and the relationship between radio bright areas and visual features of the Sun's surface.

Despite the fact that the Sun has been relatively inactive (owing to its present position in the sunspot cycle) two interesting new discoveries have been made with the Division's wide-range radio-frequency spectrograph. The first is that those special short-lived disturbances known as "outbursts" and "isolated bursts" radiate also at double the frequency, i.e. the fundamental is accompanied by a second harmonic component. The mechanisms giving rise to radiation from the disturbed Sun are not fully understood, but these observations at once rule out discontinuous processes at the source and suggest plasma oscillations, excited in the solar corona as a cloud of corpuscles is ejected through it, as a plausible and likely source. The second discovery is that it is the rule rather than the exception for "isolated bursts" to show a rapid drift towards lower frequencies—very much more rapid than that shown by "outbursts". These observations indicate that the Sun intermittently throws out clouds of particles at about one-third the velocity of light. These ejections are some hundreds of times faster than any previously known and may provide a clue to the origin of cosmic rays.

4. Cosmic Ray Research.

(University of Tasmania.)

Directional measurements of the cosmic ray intensity at Hobart have been continued during the year. The equipment, which belongs to the Australian National Antarctic Research Expedition, is being maintained and operated by Mr. R. M. Jacklyn. Data from these and earlier measurements are being examined, and should lead to publication on the diurnal variation of the east-west asymmetry.

XXX. MATHEMATICS AND MATHEMATICAL STATISTICS.

1. General.

Mathematical work plays an important part in all phases of the Organization's research programmes. A separate Division of Mathematical Statistics is maintained to provide workers in the various Divisions and Sections with specialized help in planning their researches and analysing their experimental results.

Work on mathematical instruments and mechanical and electrical methods of computation is undertaken in the Section of Mathematical Instruments.

Work on computing equipment is also undertaken in the Division of Electrotechnology (*see* Section 4 of this Chapter) and in the Division of Radiophysics (*see* Section 3 of this Chapter).

Division of Mathematical Statistics.—One of the main functions of this Division is to provide statistical assistance for officers of the Organization in the planning of experiments and the interpretation of experimental results. As a consequence, much of the Division's work is collaborative, and is described at appropriate places in other chapters. In this connexion, major developments during the past year have been the posting of Divisional officers to three new centres—the Coal Research Section, Chatswood, New South Wales, the Regional Pastoral Laboratory, Armidale, New South Wales, and the Division of Plant Industry, Brisbane—and further expansion at the McMaster Laboratory and the Division of Food Preservation and Transport, in accordance with the plan of development made some time ago.

The establishment of a Division in lieu of the former Section also constitutes a major change.

Much assistance has been given to outside bodies such as Commonwealth Departments, State Departments in all States, the universities, and commercial enterprises. Notable instances are co-operation with the Department of Territories in connexion with work for the Papua and New Guinea Department of Agriculture, Stock, and Fisheries, and with the sampling and census surveys organized for the South Pacific Commission.

The Divisional staff held its first conference during the year, and the most important outcome was the exchange of a great deal of information on problems confronting staff officers wherever situated.

Work on the analysis of rainfall records, described in previous Reports, has been completed. The statistical studies of sheep breeding in collaboration with the Division of Animal Health and Production are described in Chapter VII., Section 14. Other items of research undertaken by the Division are described in this chapter.

Following the return of an officer from a period of special training overseas, the Division is vigorously working on a programme of research in various theoretical aspects of mathematical statistics which have immediate and important applications.

Mathematical Instruments Section.—During the past year the Section has been concerned primarily with the use of the differential analyser in solving problems occurring in the electrical supply and chemical industries, in research in the ionosphere, and in the theory of globular clusters.

The development of two types of beam deflection valve for carrying out logical operations in an electronic computer is now complete. Patent applications have been lodged.

2. ANALYSIS.

(Division of Mathematical Statistics.)

(*a*) *Multivariate Analysis.*—The non-central Wishart distribution, a basic distribution of multivariate analysis, has been derived. In the course of this work, a generating function for averages over the orthogonal group was required, and this has been obtained. As this generating function is of considerable mathematical importance, its properties are now being investigated using the theory of group representations, and also its application to the calculation of the conditional moments in Bartlett's expansion of the general canonical correlation distribution.

(*b*) *Multivariate t-Distribution.*—The multivariate *t*-distribution, which arises in association with a set of normal sample deviates, has been obtained and its principal properties determined. The discovery of this exact distribution has opened a new field, and the investigations made to date have yielded a number of exact sampling distributions analagous to those which have been derived for sampling from a normal distribution. An immediate application of this work lies in the provision of exact tests of departure from normality for small samples.

(*c*) *Distribution of Range in Non-normal Populations.*—The range has long been employed as a measure of dispersion in samples from a normal population. Of particular importance is its application to quality control by variables where the control limits are based on constants involving the expectation and percentage points of the range of a certain number of independent unit normal variates. The corresponding probability integral is evidently of fundamental importance and has been tabulated by other workers.

Comparatively little is known about the distribution of range when the parent population is non-normal, although useful information, based mostly on sampling experiments, has been obtained. In this investigation, explicit expressions for the expectation and probability integral of the range for a number of non-normal populations have been derived, and their applications to quality control obtained.

(*d*) *The Hyper-Graeco Latin Square.*—The application of the graeco- and hyper-graeco latin square designs in experimental work has been known for some time, but very little information has been given regarding their statistical analysis. The object of the present investigation has been to make good this deficiency, and detailed methods for the nalysis of these types of design have now been worked out.

(*e*) *Statistical Studies on Sheep Breeding.*—These collaborative investigations between the Division of Mathematical Statistics and the Division of Animal Health and Production have continued and are reported in Chapter VII., Section 14.

3. HIGH SPEED COMPUTATION.

(Division of Radiophysics.)

Although it has not been possible yet to complete the electronic computer in accordance with the original design specification, it has been extensively used on a wide range of problems during the past year. Many of these calculations were too large or too complicated to be performed by any other means. The machine has operated at reasonable efficiency, despite the fact that work is proceeding on the rectification of technical deficiencies in some of the components, and promises to be a thoroughly useful device.

Work completed during the year includes the following calculations, which indicate the wide range of application of the machine:

(i) Computation of the relative compositions by weight of all permissible chemical compounds of carbon, hydrogen, and oxygen (40,000 values).

(ii) Analysis of data from experiments on processes involved in coal briquetting.

(iii) Evaluation of special integrals and Fourier transforms involved in radio astronomy problems; of polar diagrams for various design parameters relating to large-aperture aerials; and of the expected energy distribution across celestial objects of definite shape.

(iv) Calculations relating to water storage, including determination of design parameters for the proposed storage scheme at Blowering, New South Wales.

(v) Correlation analysis of 100 years of daily rainfall for Sydney; calculations of functions involved in the statistical theory of coalescence of raindrops; and time-series analysis of daily rainfall for selected stations throughout the world.

(vi) Calculations relating to the scattering of electrons by metal foils.

(vii) Tabulation of the complex refractive index of the ionosphere, according to the Appleton-Hartree formula.

(viii) The evaluation of various functions arising in the structural design of air frames, and in problems in optics.

4. ELECTRONIC COMPUTATION.

(Division of Electrotechnology.)

Some time ago an analogue computer for determining electron trajectories was built in conjunction with the Electrical Engineering Department of Sydney University. Although machines of this kind are very useful in electronic design, it has been recognized that they are limited to problems from which both space-charge and magnetic fields are absent. Methods have been developed to extend the range of the computer to certain space-charge and magnetic problems and in recent tests a number of these were solved successfully.

5. Differential Analyser.

(Mathematical Instruments Section.)

The differential analyser has been engaged on several long-term problems; the results of two are almost ready for publication and the others are approaching completion.

Extensions are steadily being made to the analyser to meet the requirements of new problems as they arise. In particular, a new form of adding unit has now replaced the differentials formerly used for addition and subtraction, and is giving very satisfactory results. An improved type of transmitter for the independent variable is being developed and early tests are promising.

Attention is now being given to the introduction of digital techniques into analogue devices such as the differential analyser.

XXXI. PUBLICATIONS AND INFORMATION.

1. General.

The Organization's research results are made available through various channels.

Formal scientific publication is supplemented in several ways; by the preparation of films (Section 4 of this Chapter) which may, for example, give a farmer or extension officer more help in diagnosis of animal diseases than would a list of clinical data; by the continuous and close contact with industry of officers of the Divisions and Sections, through whom much information—derived from the literature, accumulated knowledge and experience, and current research—is disseminated; by the provision of facilities for guest workers in laboratories; by the publication of trade circulars, newsletters, and articles for trade journals; by press releases; by lectures and short courses of specialized training; and by the organization of specialist conferences.

The application of research in the primary industries is being assisted by the work of the Agricultural Research Liaison Section established in 1951 (Section 3 of this Chapter).

Other sections of this Chapter describe the work of the Organization's libraries (Section 5); the Translation Section (Section 6); the Information and Documentation Sections (Section 7); and the overseas Liaison Offices (Section 8).

2. Publications.

In collaboration with the Australian National Research Council, the Organization now publishes the following eight scientific periodicals:—

Australian Journal of Agricultural Research. Issued quarterly.

Australian Journal of Applied Science. Issued quarterly.

Australian Journal of Biological Sciences. Issued quarterly.

Australian Journal of Botany. Issued as material becomes available.

Australian Journal of Chemistry. Issued quarterly.

Australian Journal of Marine and Freshwater Research. Issued as material becomes available.

Australian Journal of Physics.—Issued quarterly.

Australian Journal of Zoology. Issued as material becomes available.

General editorial policy is decided by an Editorial Board comprising Dr. N. S. Noble (Chairman), Professor J. S. Anderson, Professor Sir Macfarlane Burnet, Professor L. H. Martin, and Professor J. G. Wood. Editorial Advisory Committees are responsible for editorial matters affecting each individual journal, and members of the Board serve on appropriate journal committees.

The Royal Australian Chemical Institute collaborates in the publication of the *Australian Journal of Chemistry,* the Institute of Physics (Australian Branch) collaborates in the publication of the *Australian Journal of Physics,* and the Australian Veterinary Association and the Australian Institute of Agricultural Science collaborate in the publication of the *Australian Journal of Agricultural Research.*

The Organization's research results are published in the above-mentioned journals, in its *Bulletins* and the *Technical Papers* of its Divisions and Sections, and in special series such as the *Land Research* series and the *Soil Publication* series. Many research papers are also contributed by officers of the Organization to specialized scientific journals both in Australia and overseas.

The journals listed above are open to receive contributions of merit from research workers, irrespective of country or of the organization to which they are attached. Many papers from workers in Australian universities and a limited number from overseas have been published and the marked increase in the annual volume of the journals represents growing support from all sources.

A complete list of scientific papers published during the year by officers of the Organization will be found in Chapter XXXIV.

Other publications issued by the Organization during the year include—

(1) Volume II. of a monograph: "The Grasshoppers and Locusts (Acridoidea) of Australia", by Dr. James A. G. Rehn, dealing with part of the family Acrididae. Dr. Rehn, who is curator of Insects at the Academy of Natural Sciences of Philadelphia, is a world authority on this group.

(2) Supplement to the second edition of the "Union Catalogue of Scientific Periodicals in Australian Libraries", listing nearly 2,000 new titles including the large number of scientific and technical periodicals, both British and foreign, which have appeared in the post-war period, and showing many changes in the names of institutional and government organizations.

(3) The trade publication of the Division of Food Preservation and Transport—the *Food Preservation Quarterly*—which has been published regularly since 1941, has with Volume 14 assumed a new format and a more attractive presentation.

3. Liaison between Agricultural Research and Extension Work.

The Agricultural Research Liaison Section was formed mainly to ensure that the Organization's research results were made available to State Departments of Agriculture for use in their extension work with farmers. The work of the Section is concerned mainly with marshalling important research material and presenting it in suitable form through publications and at conferences with State extension authorities.

Officers of the Section must necessarily keep in touch with both research and extension organizations through personal contacts, including visits to research centres and attendance at conferences. Discussions with State authorities are leading to a closer research-extension linkage regarding the special problems of important regions. In some instances it has been shown that a relatively small increase in experimental work can multiply the practical effect of more fundamental research.

(*a*) *Publications.*—The periodical *Rural Research in C.S.I.R.O.* has now been established as a 32-page quarterly, and is meeting a demand for a clear and concise description of aspects of the Organization's research which can have important practical applications. Subjects requiring more detailed treatment are appearing in the Organization's "Leaflet" series. Numbers 7, 8, and 9, published during the year, dealt with various aspects of beef cattle nutrition.

(*b*) *Conferences.*—Increased interest in agricultural extension work has followed the Commonwealth extension grant to State Departments for the general purpose of increasing agricultural production, and in 1953 the first Australia-wide conference on extension work was held in Adelaide. The Section participated in this conference, which discussed new developments in the extension field and made important recommendations to the Commonwealth Government's Standing Committee on Agriculture.

Conferences between research and extension officers were held to deal with recent research results requiring more detailed explanation and discussion. The 1952 conference-tour of the Southern Tablelands of New South Wales was followed by an equally successful tour of the New England region in the spring of 1953. About 26 research and extension officers, including representatives of the Queensland Department of Agriculture and Stock and the Commonwealth Bureau of Agricultural Economics, discussed research in progress at experimental sites and reached agreement on important practical conclusions. The New South Wales Department of Agriculture compiled a detailed record of the proceedings, which will be an authoritative source on which to base further rersearch and extension work.

The Section was responsible for the organization of a conference on fleece measurement for flock improvement held in Sydney in May, 1954. This concerned work of the Organization and of State research workers which has shown that a selection procedure based on methods of measurement as an adjunct to sheep classing can substantially increase the production of present flocks and double the rate of genetic improvement. A leaflet is being prepared setting out this work in more detail.

The Section participated in the preliminary organization for research-extension conferences to be held later in 1954. A conference-tour of the Coonalpyn Downs in South Australia will include consideration of the Organization's research in that region and will be of value in the development of similar country across the Victorian border. A pasture irrigation conference will take about 60 delegates from all States through centres of research and of practical interest in Victoria and the Riverina (New South Wales).

(*c*) *Films.*—The Section works with the Film Unit in the production of films on rural topics and with the art work associated with the Unit's general activities.

(*d*) *Inquiries.*—About 1,000 inquiries were received during the year from extension workers, research officers, schools, pastoral companies, banks, individual farmers, and others interested in the agricultural development of Australia. Many were answered direct and others were referred to appropriate research or extension authorities. In several instances, the required information was supplied in the form of a report based on material obtained from several different authorities and collated by the Section.

4. Film Unit.

During the year, the following films were completed and released:—

Bovine Contagious Pleuropneumonia—16 mm., colour, sound, screening time 27 min. Produced in collaboration with the Departments of Agriculture in Victoria, New South Wales, and Queensland, this film traces the introduction and spread of the disease throughout the continent, and the nature of past and present research work of the Division of Animal Health and Production.

Design for Irrigation—16 mm., colour, sound, screening time 18 min. Produced in collaboration with the Murrumbidgee Irrigation Areas Agricultural Service of the New South Wales Department of Agriculture, this film uses a model of an actual, typical irrigation holding to show how to survey and lay out a new irrigation area, and how to redesign an existing planting to remedy typical faults.

The Sharpening and Maintenance of Power Saw Chains—16 mm., black and white, sound, screening time 13 min. Produced in collaboration with the Division of Forest Products, this film is designed to instruct chain saw operators in how to keep their equipment in efficient operating condition.

The Argentine Ant—16 mm., colour, sound, screening time 10 min. This film, released in the previous year, has been modified to make it more suitable for use by local health authorities.

Films on the following subjects are in the course of production:—

The Mutton Birds of Bass Strait—16 mm., colour, sound. This film has almost been completed but awaits a sequence depending on seasonal conditions.

Two Blades of Grass—16 mm., colour, sound, being produced in collaboration with the New South Wales Department of Agriculture. This film shows the role of a vigorously growing legume in pasture improvement and crop rotation in southern Australia.

Supply and Drainage Ditches—16 mm., colour, sound, being produced in collaboration with the New South Wales Department of Agriculture. This film shows the correct design, layout, and construction of supply and drainage ditches.

War Against the Rabbit—16 mm., colour, sound, being produced for the Victorian Department of Land and Surveys. This film describes the steps necessary in tackling the problem of eradication of rabbits.

Acute Phalaris Staggers in Sheep—16 mm., black and white, sound. The film records the appearances and symptoms of acutely affected experimental sheep grazing on predominantly phalaris pastures.

Meiosis—16 m.m., colour, sound, describing in detail the stages in the chromosome reduction division of cells.

5. Libraries.

A Supplement to the *Union Catalogue of Scientific Periodicals in Australian Libraries* has been published during the year. This Supplement covers the titles of 1926 new periodicals which have commenced publication between 1946 and 1952 only, and is an indication of the considerable increase in scientific publication in the post-war years. The number of co-operating raries in this Supplement remains much the same in the second edition, which appeared in 1951. There re, however, been a number of alterations in titles l addresses. Arrangements are now being made the preparation of a complete supplement which s hoped will appear within the next two years.

The National Library, Canberra, has now included Organization's Head Office library as one of the ository centres for cards of their *Union Catalogue Periodicals in the Social Sciences and Humanities.* is, when used in conjunction with the *Union talogue of Scientific Periodicals*, makes it possible trace almost all the periodical literature available libraries in the Commonwealth.

The Organization's library system now consists of library at Head Office and 37 branch libraries ecializing in the subject-matter of most use to the vision, Section, or Laboratory to which each is ached. Practically the whole of the material is ly catalogued, and with the except of subject entries, rds for all holdings are available in the central catague held at Head Office.

A system of multiple loan forms is used between the raries for locating and lending material, which luces clerical work to a minimum and makes the ntents of all the libraries available to officers anyere.

Several of the Divisional libraries have installed the all portable units which are now available for otographing and developing library material *in situ.* is equipment helps to solve the problem of making rnal material available when the publications themves cannot be spared from the library.

With the increase in volume and substance of pubations issued by the Organization, the exchange sition continues to improve and material is being eived from research institutions throughout the rld. This is not confined only to periodicals and ials, but frequently includes even text-books supplied complete the documentation in various fields.

6. Translation.

The Translation Section has performed translation, th written and oral, for the Organization's Divisions d Sections. Some slight assistance in oral translan has been given to other governmental bodies and entific workers. Owing to difficulty encountered in ff replacement, a considerable amount of work has d to be sent to outside translators.

The Section has acted as Australian agent for the dex of Translations of the British Commonwealth ientific Office. A reference card index of availle translations has been kept and its existence advered. The use made of it has not been extensive. A ge number of cards relating to translations held by Library of Congress in the United States have en received by the Section and added to the index.

The languages handled by the Translation Section : German, Dutch, Swedish, Norwegian, Danish, elandic, Latin, French, Italian, Spanish, Portuguese, ebrew, Russian, Polish, Ukranian, and Lettish. r other languages, use is made of a panel of outside inslators.

7. Information and Documentation.

The bulk of the information work undertaken by the ganization is still handled by the Divisions and ctions, as a result of direct inquiries. A small infortion staff attached to the Secretariat, whose main ty is to refer inquiries to the specialist either within without the Organization, is maintained at Head fice; in the course of this work, however, a large mber of inquiries which involve correspondence and making of literature surveys are handled direct.

8. Overseas Liaison Offices.

The Organization has Scientific Liaison Offices in London and Washington as constituent units of the British Commonwealth Scientific Office (London) and the British Commonwealth Scientific Office (North America). These offices maintain close contact with overseas scientific developments and also act as bases for visitors and research students from the Organization and for other visiting scientists.

In London, the Chief Scientific Liaison Officer has represented Australian interests at a number of international and United Kingdom scientific conferences and committees, and thus developed closer contacts and understanding on many matters. The London Office has materially assisted with regard to the enlistment of research staff, not only in the United Kingdom but also in other European countries, especially Holland. The Washington Office has also contributed greatly to Australian representation at conferences and meetings held in the United States of America.

XXXII. PERSONNEL OF COUNCIL AND COMMITTEES.

1. Executive.

Sir Ian Clunies Ross, C.M.G., D.V.Sc. (*Chairman*).
F. W. G. White, C.B.E., M.Sc., Ph.D. (*Chief Executive Officer*).
S. H. Bastow, D.S.O., B.Sc., Ph.D.
H. J. Goodes, O.B.E., B.A.
A. B. Ritchie, M.A.

2. Advisory Council.

Chairman.

Sir Ian Clunies Ross, C.M.G., D.V.Sc.

Executive.

(*See* above.)

Chairman of State Committees.

New South Wales—Professor J. P. Baxter, O.B.E., B.Sc., Ph.D.
Victoria—R. S. Andrews, D.Sc.
Queensland—A. F. Bell, M.Sc., D.I.C.
South Australia—Professor J. G. Wood, Ph.D., D.Sc.
Western Australia—Professor E. J. Underwood, B.Sc.(Agric.), Ph.D.
Tasmania—S. L. Kessell, M.B.E., M.Sc., Dip.For.

Co-opted Members.

D. T. Boyd, C.M.G.
L. B. Bull, C.B.E., D.V.Sc.
Sir Macfarlane Burnet, M.D., Ph.D., F.R.S.
The Hon. O. McL. Falkiner, M.L.C.
W. A. Gunn.
D. R. Hawkes.
E. H. B. Lefroy.
D. Mackinnon.
I. M. McLennan, B.E.E.
Emeritus Professor Sir John Madsen, B.E., D.Sc.
Professor L. H. Martin, C.B.E., Ph.D.
Professor D. M. Myers, B.Sc., D.Sc.Eng.
Professor M. L. Oliphant, M.A., Ph.D., D.Sc., LL.D., F.R.S.
G. B. O'Malley, B.Met.E.
Sir David Rivett, K.C.M.G., M.A., D.Sc., F.R.S.
Professor S. M. Wadham, M.A., Agr.Dip.

3. State Committees.

New South Wales.

Professor J. P. Baxter, O.B.E., B.Sc., Ph.D. (*Chairman*).
Emeritus Professor Sir Henry Barraclough, K.B.E., V.D., B.E., M.M.E.
F. S. Bradhurst.

V. J. F. Brain, B.E.
J. N. Briton, B.Sc., B.E.
Sir Harry Brown, C.M.G., M.B.E.
Professor H. R. Carne, D.V.Sc.
S. F. Cochran.
The Hon. O. McL. Falkiner, M.L.C.
W. R. Hebblewhite, B.E.
E. L. S. Hudson.
The Hon. Sir Norman Kater, M.L.C., M.B., Ch.M.
J. F. Litchfield.
Professor P. R. McMahon, M.Agr.Sc., Ph.D.
Sir Frederick McMaster.
Professor J. R. A. McMillan, D.Sc.Agr., M.S.
Emeritus Professor Sir John Madsen, B.E.. D.Sc.
J. Merrett.
C. St. J. Mulholland, B.Sc.
Professor D. M. Myers, B.Sc., D.Sc.Eng.
R. J. Noble, B.Sc.Agr., M.Sc., Ph.D.
R. P. Okeden.
J. G. Peake.
A. R. Penfold, A.S.T.C., F.R.A.C.I.
Professor D. W. Phillips, B.Sc., Ph.D.
H. F. Prell.
L. A. Pockley, B.V.Sc.
Associate Professor F. H. Reuter, Ph.D.
T. C. Roughley, B.Sc.
J. P. Tivey, B.A., B.Sc., B.E.
J. Vernon, B.Sc., Ph.D.
Emeritus Professor W. L. Waterhouse, M.C., D.Sc.Agr., D.I.C.
Emeritus Professor R. D. Watt, M.A., B.Sc.
C. M. Williams.

Victoria.

R. S. Andrews, D.Sc. (*Chairman*).
D. T. Boyd, C.M.G.
N. K. S. Brodribb, C.B.E., F.I.C., M.I.P.E., A.R.A.C.I.
Sir Macfarlane Burnet, M.D., Ph.D., F.R.S.
L. B. Bull, C.B.E., D.V.Sc.
J. R. S. Cochrane, B.Sc.
G. A. Cook, M.C., O.B.E., M.Sc., B.H.E.
Professor J. N. Greenwood, D.Sc., M.Met.E.
Sir Russell Grimwade, C.B.E., B.Sc.
Professor E. J. Hartung, D.Sc.
H. Herman, D.Sc., M.M.E., B.C.E.
Professor E. S. Hills, D.Sc., Ph.D., D.I.C., F.R.S.
R. A. Hunt, D.S.O., B.C.E.
Associate Professor G. W. Leeper, M.Sc.
Emeritus Professor Sir Peter MacCallum, M.C., M.A., M.Sc., M.B., Ch.B.
D. Mackinnon
I. M. McLennan, B.E.E.
H. A. Mullett, B.Agr.Sc.
G. B. O'Malley, B.Met.E.
Sir David Rivett, K.C.M.G., M.A., D.Sc., F.R.S.
D. E. Thomas, D.Sc.
Professor J. S. Turner, M.A., Ph.D., M.Sc.
Professor S. M. Wadham, M.A., Dip.Agr.
W. E. Wainwright.
L. J. Weatherley, M.A.
Emeritus Professor H. A. Woodruff, B.Sc.

Queensland.

A. F. Bell, M.Sc., D.I.C. (*Chairman*).
R. J. Donaldson, D.S.O., B.C.E.
J. R. Duggan, B.Sc., B.E.
Professor T. K. Ewer, B.V.Sc., Ph.D.
V. Grenning.
W. A. Gunn.
R. L. Harrison.
Professor D. A. Herbert, D.Sc.
C. H. Jamieson.
Professor T. G. H. Jones, D.Sc.
N. J. King.
A. McCulloch, M.E.
Professor W. V. Macfarlane, M.A., M.D., Ch.B.
J. F. Meynink.
J. Michelmore.
I. W. Morley, B.M.E., B.Met.E.
O. E. J. Murphy, M.D., M.Ch.M.
Professor M. Shaw, M.E., M.Mech.E.
B. Flewell-Smith.
Professor W. Stephenson, B.Sc., Ph.D.
W. A. T. Summerville, D.Sc.
Professor L. J. H. Teakle, B.Sc.Agr., M.S., Ph.D.
S. A. Trout, M.Sc., Ph.D.
H. C. Urquhart, M.Sc.
R. Veitch, B.Sc.Agr., B.Sc.For.
Professor H. C. Webster, D.Sc., Ph.D.
W. Webster, B.V.Sc.
Professor F. T. M. White, B.Met.E., B.E.
M. White, M.Sc., Ph.D.
Associate Professor F. W. Whitehouse, D.Sc., Ph.D.
W. Young.

South Australia.

Professor J. G. Wood, Ph.D., D.Sc. (*Chairman*).
A. J. Allen.
B. H. Bednall, B.Sc.
A. R. Callaghan, C.M.G., B.Sc., B.Sc.Agr., D.Phil.
Professor D. G. Catcheside, M.A., D.Sc., F.R.S.
S. B. Dickinson, M.Sc.
Emeritus Professor Sir Kerr Grant, M.Sc.
C. Haselgrove.
J. C. Hawker, B.A.
Hawkes, D. R.
O. H. Heinrich.
Professor L. G. H. Huxley, M.A., D.Phil.
W. S. Kelly, O.B.E.
R. N. McCulloch, M.B.E., D.Sc.(Agr.), B.Sc.
H. R. Marston, F.R.S.
Emeritus Professor Sir Douglas Mawson, O.B.E., D.Sc., B.E., F.R.S.
Professor M. L. Mitchell, M.Sc.
F. W. Moorhouse, M.Sc.
F. T. Perry, M.B.E.
Professor J. A. Prescott, C.B.E., D.Sc., F.R.S.
Professor E. A. Rudd, A.M., B.Sc.
W. L. Sanderson, O.B.E., M.C., C.deG.
E. M. Schroder.
A. M. Simpson, B.Sc.
Professor E. C. R. Spooner, B.E., D.Sc., D.Phil.

Western Australia.

Professor E. J. Underwood, B.Sc.(Agr.), Ph.D. (*Chairman*).
Professor N. S. Bayliss, B.A., B.Sc., Ph.D.
H. Bowley.
F. G. Brinsden.
D. W. Brisbane.
C. R. Bunning, B.C.E.
Professor C. J. Birkett Clews, B.Sc., Ph.D.
Professor K. L. Cooper, B.Sc., M.A.
A. J. Fraser.
B. J. Grieve, M.Sc., Ph.D.
P. H. Harper, B.A.
A. C. Harris, B.Sc.
G. K. Baron-Hay, M.C., B.Sc.(Agr.).
E. H. B. Lefroy.
Sir Langley Lefroy, M.C.
B. Meecham.
Professor R. T. Prider, B.Sc., Ph.D.
Emeritus Professor A. D. Ross, C.B.E., M.A., D.Sc.
H. P. Rowledge.
W. J. Russell.
G. L. Sutton, C.M.G., D.Sc.Agr.
D. O. Temby, B.E.
N. Temperley.
Professor H. Waring, D.Sc.

Tasmania.

L. Kessell, M.B.E., M.Sc., Dip.For. (*Chairman*).
ofessor H. N. Barber, M.A., Ph.D.
R. S. Benjamin.
Brodribb.
ofessor A. Burn, M.Sc., B.E., LL.D.
H. Crane, B.Sc.
H. Foster, B.C.E.
A. Frankcomb.
W. Hicks.
. S. Kirby, B.E.
W. Knight, M.E., B.Sc., B.Com.
H. Peacock.
Pearson, D.Sc.
ie Hon. Sir Rupert Shoobridge, M.L.C.
. B. Somerset, M.Sc.

4. Committee of Review—Agricultural and Pastoral Problems.

r Ian Clunies Ross, C.M.G., D.V.Sc., C.S.I.R.O. (*Chairman*).
B. Bull, C.B.E., D.V.Sc., Division of Animal Health and Production, C.S.I.R.O.
S. Christian, B.Sc.Agr., M.S., Land Research and Regional Survey Section, C.S.I.R.O.
. C. Forster, M.Agr.Sc., Ph.D., C.S.I.R.O.
H. Frankel, D.Sc., D.Agr., F.R.S., Division of Plant Industry, C.S.I.R.O.
. R. Marston, F.R.S., Division of Biochemistry and General Nutrition, C.S.I.R.O.
J. Nicholson, D.Sc., Division of Entomology, C.S.I.R.O.
N. Ratcliffe, B.A., Wildlife Survey Section, C.S.I.R.O.
K. Taylor, B.A., M.Sc., B.Sc.Agr., Division of Soils, C.S.I.R.O.
. Ives, M.Ec., C.S.I.R.O. (*Secretary*).

. Commonwealth Research Station, Merbein—Technical Committee.

ofessor J. A. Prescott, C.B.E., D.Sc., F.R.S., Waite Agricultural Research Institute, University of Adelaide (*Chairman*).
A. T. Ballard, Ph.D., M.Agr.Sc., Division of Plant Industry, C.S.I.R.O.
Barnard, D.Sc., Division of Plant Industry, C.S.I.R.O.
J. Casey, Commonwealth Dried Fruits Control Board.
. B. Hawson, representing Consultative Committee.
Malloch, M.B.E., Commonwealth Dried Fruits Control Board.
K. Taylor, B.A., M.Sc., B.Sc.Agr., Division of Soils, C.S.I.R.O.
Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein (*Secretary*).

. Commonwealth Research Station, Merbein—Consultative Committee.

. B. Hawson, First Mildura Irrigation Trust (*Chairman*).
W. Andrew, Waikerie, South Australia.
. J. Balcombe, Robinvale.
. Broadfoot, Department of Agriculture, New South Wales.
E. Cameron, Red Cliffs Settlement.
J. Casey, representing Technical Committee.
T. Cook, Curlwaa Fruit-growers' Association.
W. Cockcroft, Nyah-Woorinen Enquiry Committee.
E. Cole, B.Agr.Sc., Department of Agriculture, Victoria.
Drummond, B.C.E., State Rivers and Water Supply Commission, Victoria.
R. E. Ferguson, Dried Fruits Association, Woorinen.
W. V. Ford, Mildura Packers' Association.
J. R. Gordon, Citrus Growers' Association, Merbein.
A. E. Hazel, Dried Fruits Association, Red Cliffs.
S. Heaysman, Coomealla, New South Wales.
G. Hobson, Nyah-Woorinen Enquiry Committee.
F. J. Hollins, Wakool Land-Use Committee.
H. Jackson, Wakool Land-Use Committee.
J. A. Lockhead, Mildura Shire Council.
A. R. McDougall, Merbein.
P. Malloch, M.B.E., representing Technical Committee.
F. S. Oldham, Dip.Agr. (W.A.), Department of Agriculture, New South Wales.
C. T. Polkinghorne, Loxton North.
R. C. Polkinghorne, Nyah-Woorinen Enquiry Committee.
J. L. Showell, Renmark Irrigation Trust.
A. G. Strickland, C.B.E., M.Agr.Sc., Department of Agriculture, South Australia.
G. Swan, Nyah-Woorinen Enquiry Committee.
A. L. Tisdall, M.Agr.Sc., State Rivers and Water Supply Commission, Victoria.
E. S. West, B.Sc., M.S., Irrigation Research Station, C.S.I.R.O., Griffith, New South Wales.
O. Weste, Renmark, South Australia.
F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein (*Secretary*).

7. Wakool Land-Use Committee.

F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein (*Chairman*).
F. J. Hollins, Wakool District Landholders' Association (*Deputy Chairman*).
F. Bock, Tullakool.
F. I. Bolton, Water Conservation and Irrigation Commission, New South Wales.
R. J. Hanson, Rural Bank of New South Wales, Deniliquin.
C. Hood, H.D.A., Department of Agriculture, New South Wales.
R. W. Horn, Water Conservation and Irrigation Commission, New South Wales.
K. Howe, Rural Bank of New South Wales, Deniliquin.
L. A. Jeffers, Wakool District Landholders' Association.
D. S. Jones, Tulla.
D. F. Keeley, H.D.A., Department of Agriculture, New South Wales.
W. McDermott, Wakool District Landholders' Association.
R. W. Prunster, B.Sc.(Agric.), Regional Pastoral Laboratory, C.S.I.R.O., Deniliquin.
W. R. A. Smith, Wakool District Landholders' Association.
D. Thomas, Wakool District Landholders' Association.
A. Varcoe-Cocks, Wakool Shire Council.
H. Jackson, Wakool District Landholders' Association (*Secretary*).

8. Irrigation Research Station, Griffith—Technical Committee.

H. N. England, B.Sc., Water Conservation and Irrigation Commission, New South Wales.
O. H. Frankel, D.Sc., D.Agr., F.R.S., Division of Plant Industry, C.S.I.R.O.
F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
Professor J. A. Prescott, C.B.E., D.Sc., F.R.S., Waite Agricultural Research Institute, University of Adelaide.
J. K. Taylor, B.A., M.Sc., B.Sc.Agr., Division of Soils, C.S.I.R.O.
V. C. Williams, representing Irrigation Research and Extension Committee.
E. S. West, B.Sc., M.S., Irrigation Research Station, Griffith (*Secretary*).

9. IRRIGATION RESEARCH AND EXTENSION COMMITTEE (MURRUMBIDGEE IRRIGATION AREAS).

V. C. Williams, Griffith Producers' Co-operative Society (*Chairman*).
A. E. Bowmaker, Rice Growers' Association, Leeton.
J. C. Byrne, Leeton Co-operative Cannery.
E. S. Clayton, Soil Conservation Service, New South Wales.
P. Crook, M.I.A. District Council of Extension Groups, Hanwood.
G. S. Denne, M.I.A. District Council of Extension Groups, Leeton.
H. N. England, B.Sc., Water Conservation and Irrigation Commission, New South Wales.
B. O. French, B.Sc.Agr., Department of Agriculture, Yanco, New South Wales.
G. E. B. Good, Rural Bank of New South Wales, Leeton.
J. E. Harris, Leeton Fruit Growers' Co-operative, Leeton.
S. J. Hinton, Rice Growers' Association, Leeton.
W. N. Hogan, M.I.A. District Council of Extension Groups.
H. J. Hynes, D.Sc.Agr., M.S., Department of Agriculture, New South Wales.
E. R. Iredale, Irrigation Agency, Rural Bank of New South Wales.
R. McLeary, M.I.A. Vegetable Growers' Association, Leeton.
Professor J. R. A. McMillan, D.Sc.Agr., M.S., University of Sydney.
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F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
R. W. Prunster, B.Sc.Agr., Regional Pastoral Laboratory, C.S.I.R.O., Deniliquin.
C. E. Sharam, Rice Growers' Association, Griffith.
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E. S. West, B.Sc., M.S., Irrigation Research Station, C.S.I.R.O., Griffith.
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10. REGIONAL PASTORAL LABORATORY, DENILIQUIN—TECHNICAL COMMITTEE.

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E. R. Ennals, Cobram Irrigation District, Cobram, Victoria.
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H. Broadfoot, Department of Agriculture, New South Wales.
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F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
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C. M. Dimond, Public Works Department, Western Australia.
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W. M. Nunn, Department of Agriculture, Western Australia (*Executive Officer*).

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W. Nixon-Smith, B.Sc.Agr., Agricultural Officer, Northern Territory Administration.

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C. P. Haselgrove, representing the Federal Viticultural Council.
H. R. Haselgrove, representing the Australian Wine Board.

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. W. Wark, D.Sc., Ph.D., Division of Industrial Chemistry, C.S.I.R.O.
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E. J. Stewart, B.Sc., Postmaster-General's Department.
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XXXIII. STAFF.

The following is a list of the staff of the Organization as at 30th June, 1954. The list does not include clerical staff, typists, technical assistants, and miscellaneous workers.

1. Head Office.

(Head-quarters: 314 Albert-street, East Melbourne.)

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Chief Executive Officer—F. W. G. White, C.B.E., M.Sc., Ph.D.
Executive Officer—S. H. Bastow, D.S.O., B.Sc., Ph.D.
Assistant Executive Officer—H. C. Forster, M.Agr.Sc., Ph.D.
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Secretary (Industrial and Physical Sciences) and Acting Secretary (Agricultural and Biological Sciences) —G. B. Gresford, B.Sc., A.M.T.C.
Secretary (Finance and Supplies)—M. G. Grace, A.A.S.A.
Assistant Secretary (General Administration)—D. T. C. Gillespie, M.Sc.
Assistant Secretary (Agricultural and Biological Sciences)—P. F. Butler, M.Sc.Agr.
Senior Principal Research Officer—J. E. Cummins, B.Sc., M.S.
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At National Cattle Breeding Station, "Belmont", Rockhampton, Queensland—
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10. Dairy Research Section.

(Head-quarters: Lorimer-street, Fishermen's Bend, Victoria.)

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11. Division of Electrotechnology.

(Head-quarters: National Standards Laboratory at University of Sydney.)

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12. Division of Entomology.

(Head-quarters: Canberra, Australian Capital Territory.)

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    Assistant Chief—D. F. Waterhouse, D.Sc.
    Technical Secretary—K. L. Taylor, B.Sc.Agr.
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    Research Officer—Miss M. Fielding, B.Sc., Ph.D.
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    Research Officer—T. G. Campbell.
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    Senior Research Officer—S. J. Paramonov, D.Sc.
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    Principal Research Officer—K. H. L. Key, D.Sc.
    Technical Officer—L. J. Chinnick, R.D.A.
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    Senior Research Officer—F. J. Gay, B.Sc., D.I.C.
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    Senior Research Officer—T. Greaves.
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    Senior Research Officer—I. F. B. Common, M.A., M.Agr.Sc. (abroad).
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Potato Moth and Taxonomy of Hymenoptera—
    Senior Research Officer—E. F. Riek, M.Sc.
At Yeerongpilly, Queensland—
  Cattle Tick Investigations—
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    Research Officer—W. J. Roulston, B.Sc.
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At Rockhampton, Queensland—
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At Sydney—
Biological Control—
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13. DIVISION OF FISHERIES.

(Head-quarters: Cronulla, New South Wales.)

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Principal Research Officer—D. J. Rochford, B.Sc.
Principal Research Officer—E. J. Ferguson Wood, B.A., M.Sc.
Senior Research Officer—I. S. R. Munro, M.Sc.
Senior Research Officer—J. M. Thomson, M.Sc.
Research Officer—R. S. Spencer, B.Sc.
Research Officer—Miss P. Kott, M.Sc.
Research Officer—G. S. Grace, B.Sc.
Research Officer—T. W. Houston, B.Sc.
Technical Officer—J. P. Robins, B.Sc.
Technical Officer—H. R. Jitts, B.Sc.
Technical Officer—R. F. Mitchell, M.Sc.
Technical Officer—D. Thompson, Dip.Appl.Chem.
Technical Officer—I. R. Kaplan, M.Sc.
Technical Officer—Miss B. B. Dew, B.A.

At Melbourne—
Technical Officer—P. E. Gartner, B.Sc.

At Perth—
Senior Research Officer—K. Sheard, D.Sc.
Research Officer—W. B. Malcolm, B.Sc.
Research Officer—R. G. Chittleborough, B.Sc.
Research Officer—R. W. George, B.Sc.
Technical Officer—A. Middleton, Dip.Chem.

At Hobart—
Senior Research Officer—A. G. Nicholls, B.Sc., Ph.D.
Senior Research Officer—A. M. Olsen, M.Sc.
Research Officer—A. H. Weatherley, B.Sc.
Research Officer—T. R. Cowper, B.Sc.
Research Officer—D. E. Kurth, B.Sc.
Technical Officer—A. B. Jack, B.Sc.

At Dunwich, Queensland—
Technical Officer—D. J. Dunstan, B.Sc.

At Thursday Island, Queensland—
Research Officer—J. S. Hynd, B.Sc.
Technical Officer—D. J. Tranter, B.Sc.

14. DIVISION OF FOOD PRESERVATION AND TRANSPORT.

(Head-quarters: State Abattoir, Homebush Bay, New South Wales.)

At Homebush, New South Wales—
Administration and General—
Chief—J. R. Vickery, M.Sc., Ph.D.
Technical Secretary—R. B. Withers, M.Sc., Dip.Ed.
Technical Officer—Miss E. M. Christie, B.Sc.
Senior Librarian—Miss B. Johnston, B.Sc.

Physics and Transport Section—
Senior Principal Research Officer—E. W. Hicks, B.A., B.Sc.
Senior Research Officer—M. C. Taylor, M.Sc.
Research Officer—G. M. Rostos, Dipl.Ing.
Research Officer—H. L. Evans, M.Sc.
Technical Officer—Miss J. A. Hiscox, B.Sc.

Microbiology Section—
Principal Research Officer—W. J. Scott, B.Agr.Sc.
Senior Research Officer—W. G. Murrell, B.Sc.Agr., D.Phil.
Research Officer—J. H. B. Christian, B.Sc.Agr.
Senior Technical Officer—D. F. Ohye, D.I.C.
Technical Officer—Miss B. J. Marshall, A.S.T.C.

Biochemistry Investigations—
Principal Research Officer—F. E. Huelin, B.Sc., Ph.D.
Research Officer—J. B. Davenport, M.Sc.

Organic Chemistry Investigations—
Senior Research Officer—Miss T. M. Reynolds, M.Sc., D.Phil.
Research Officer—A. S. F. Ash, B.Sc., Ph.D.
Research Officer—E. F. L. J. Anet, M.Sc., Ph.D.

Fruit and Vegetable Storage Section—
Senior Research Officer—E. G. Hall, B.Sc.Agr.
Research Officer—Miss J. M. Bain, M.Sc.
Technical Officer—T. J. Riley, H.D.A.
Technical Officer—J. A. Casey, A.M.T.C.

Plant Biochemistry Investigations—
Senior Research Officer—J. T. Turner, M.Sc., Ph.D.
Technical Officer—Mrs. D. H. Turner, M.Sc., Ph.D.

Canning and Fruit Products Section—
Principal Research Officer—L. J. Lynch, B.Agr.Sc.
Principal Research Officer—J. F. Kefford, M.Sc.
Senior Research Officer—R. S. Mitchell, M.Sc.Agr.
Research Officer—B. V. Chandler, B.Sc.
Research Officer—E. G. Davis, B.Sc.
Research Officer—P. W. Board, B.Sc.
Technical Officer—T. A. Meyer, Dipl.Agr.

Dried Foods Section—
Research Officer—D. McG. McBean, B.Sc.

Fish Preservation Investigations—
Principal Research Officer—W. A. Empey, B.V.Sc.

Egg Investigations—
Chief—J. R. Vickery, M.Sc., Ph.D.
Technical Officer—F. S. Shenstone, A.S.T.C.

Freezing of Fruit and Vegetables—
Research Officer—I. J. Tinsley, B.Sc. (overseas).
Research Officer—J. H. Scheltema, M.Sc.

At Auburn, New South Wales—
Meat Dehydration Investigations—
Research Officer—A. R. Prater, B.Sc.Agr.

At Botany School, University of Sydney—
Plant Physiology Investigations—
Senior Principal Research Officer—R. N. Robertson, B.Sc., Ph.D.
Senior Research Officer—H. S. McKee, B.A., D.Phil.
Research Officer—Miss M. Wilkins, M.Sc.
Research Officer—Mrs. J. Pearson, M.Sc.
Research Officer—A. B. Hope, B.Sc., Ph.D.
Technical Officer—Mrs. L. Nesztel, B.Sc.

At Botany School, University of Melbourne—
Plant Physiology Investigations—
Research Officer—K. S. Rowan, M.Sc.

At Biochemistry School, University of Sydney—
Physical Chemistry Section—
Research Officer—H. A. McKenzie, M.Sc.
Research Officer—J. J. Macfarlane, M.Sc.
Technical Officer—M. B. Smith, A.S.A.S.M.

At Tasmanian Regional Laboratory, Hobart—
Canning and Fruit Products—
Technical Officer—R. A. Gallop, A.S.T.C.
Fish Preservation Investigations—
Technical Officer—K. W. Anderson, A.M.T.C.

At Cannon Hill, Queensland—
Meat Investigations—
Officer-in-charge—A. Howard, M.Sc.
Senior Research Officer—G. Kaess, Dr.Ing.
Research Officer—A. D. Brown, M.Sc.
Research Officer—H. L. Webster, B.Sc., Ph.D.
Technical Officer—N. T. Russell, D.I.C.
Technical Officer—P. E. Bouton, B.Sc.
Technical Officer—M. F. Meaney, B.Sc.

With United Kingdom Ministry of Food—
Senior Research Officer—N. E. Holmes, B.E.E., M.Mech.E. (seconded).

With Commonwealth Department of Commerce and Agriculture, Sydney—
Research Officer—J. Shipton, B.Sc.Agr. (seconded).

15. DIVISION OF FOREST PRODUCTS.

(Head-quarters: 69 Yarra Bank-road, South Melbourne, Victoria.)

Administration—
Chief—S. A. Clarke, B.E.
Assistant to Chief—C. S. Elliott, B.Sc.
Assistant to Chief—H. E. Dadswell, D.Sc.
Technical Secretary—F. A. Priest, A.S.A.S.M.
Research Officer—A. P. Wymond, M.Sc.
Senior Librarian—Miss M. I. Hulme.
Senior Technical Officer—L. Santer, Dip.Eng.
Technical Officer—P. J. Moglia, Dip.Mech.Eng.

Wood and Fibre Structure Section.—
Senior Principal Research Officer—H. E. Dadswell, D.Sc.
Principal Research Officer—A. B. Wardrop, M.Sc., Ph.D.
Senior Research Officer—Miss M. M. Chattaway, M.A., B.Sc., D.Phil.
Senior Research Officer—W. E. Hillis, M.Sc., A.G.Inst. Tech.
Senior Research Officer—H. D. Ingle, B.For.Sc.
Senior Research Officer—I. V. Newman, M.Sc., Ph.D.
Technical Officer—Miss M. F. Day, B.Sc.
Technical Officer—C. F. James, B.Sc.
Technical Officer—J. W. P. Nicholls, B.Sc.

Wood Chemistry Section—
Senior Principal Research Officer—W. E. Cohen, D.Sc.
Principal Research Officer—D. E. Bland, M.Sc.
Senior Research Officer—H. G. Higgins, B.Sc.
Senior Research Officer—R. C. McK. Stewart, B.Sc.
Senior Research Officer—A. J. Watson, A.M.T.C.
Research Officer—Miss J. F. Hobden, B.Sc.
Research Officer—A. von Koeppen, Dr.Ing.
Technical Officer—Miss V. Goldsmith, A.M.T.C.
Technical Officer—A. W. McKenzie, A.M.T.C.
Technical Officer—J. A. McPherson, B.Sc. (on leave).
Technical Officer—Mrs. R. Payne, B.Sc.
Technical Officer—Miss G. Schwerin, B.Sc.
Technical Officer—Mrs. E. F. Frydman, B.Sc.
Technical Officer—Miss C. Stamp, B.Sc.

Timber Physics Section—
Principal Research Officer—R. S. T. Kingston, B.Sc., B.E.
Senior Research Officer—G. N. Christensen, Ph.D., M.Sc.
Senior Research Officer—L. N. Clarke, M.Mech.E., B.Eng.Sc.
Research Officer—Miss K. E. Kelsey, B.Sc.
Technical Officer—L. D. Armstrong, A.M.T.C.
Technical Officer—N. C. Edwards, A.S.M.B.
Technical Officer—P. U. A. Grossman, Ph.A.Mr.

Timber Mechanics Section—
Principal Research Officer—J. D. Boyd, M.C.E.
Senior Research Officer—N. H. Kloot, M.Sc.
Senior Research Officer—R. G. Pearson, B.A., B.C.E.
Technical Officer—J. J. Mack, A.M.T.C.
Technical Officer—K. B. Schuster, A.M.T.C.
Technical Officer—Miss A. Ryan, A.M.T.C.

Timber Seasoning Section—
Principal Research Officer—G. W. Wright, M.E.
Senior Research Officer—J. W. Gottstein, B.Sc.
Research Officer—W. G. Kauman, B.Sc., A.M.T.C.
Senior Technical Officer—L. J. Brennan.
Technical Officer—F. J. Christenson, A.M.T.C.

Timber Preservation Section—
Principal Research Officer—N. Tamblyn, M.Sc. (Agric.).
Senior Research Officer—E. W. B. Da Costa, M.Agr.Sc.
Senior Research Officer—E. L. Ellwood, M.Sc.(For.), Ph.D.
Research Officer—Miss S. J. Wilson, M.Sc.
Research Officer—Miss M. E. Lancaster, M.Sc. (temporary).
Senior Technical Officer—J. Beesley, Dip.For., M.Sc.(For.).
Senior Technical Officer—F. A. Dale, Dip.Mech. Eng.
Senior Technical Officer—N. E. M. Walters, B.Sc.
Technical Officer—T. E. H. Aplin, B.Sc.

Veneer and Gluing Section—
Senior Research Officer—A. Gordon, B.Sc.
Research Officer—K. F. Plomley, B.Sc.(Agr.).

Timber Utilization Section—
Senior Principal Research Officer—R. F. Turnbull, B.E.
Research Officer—W. M. McKenzie, B.Sc.(For.).
Technical Officer—D. S. Jones, B.C.E.
Technical Officer—R. L. Cowling, Dip.Mech.Eng., Dip.E.E.

16. DIVISION OF INDUSTRIAL CHEMISTRY.

(Head-quarters: Lorimer-street, Fishermen's Bend, Victoria.)

Administration—
Chief—I. W. Wark, D.Sc., Ph.D. (abroad).
Divisional Secretary—L. Lewis, B.Met.E.
Assistant Secretary—A. E. Scott, M.Sc.

Minerals Utilization Section—
Senior Principal Research Officer—R. G. Thomas, B.Sc.
Principal Research Officer—T. R. Scott, D.Sc., B.Ed.
Principal Research Officer—A. Walkley, B.A., D.Sc., Ph.D.
Principal Research Officer—A. W. Wylie, M.Sc., Ph.D.
Senior Research Officer—R. C. Croft, M.Sc.
Senior Research Officer—F. K. McTaggart, M.Sc.
Senior Research Officer—I. E. Newnham, M.Sc.
Senior Research Officer—A. D. Wadsley, M.Sc.
Research Officer—P. M. J. Gray, B.Sc.(Hons.), A.R.S.M.

Research Officer—D. F. A. Koch, B.Sc.(Hons.).
Research Officer—E. S. Pilkington, A.S.T.C.
Research Officer—D. E. Scaife, B.Sc.(Hons.).
Research Officer—A. G. Turnbull, B.Chem.Eng. (Hons.).
Senior Technical Officer—H. R. Skewes, A.A.C.I.
Technical Officer—Miss I. J. Bear, A.M.T.C.
Technical Officer—Miss E. E. Rutherford, B.Sc.

Cement and Ceramics Section—

Principal Research Officer—A. J. Gaskin, M.Sc. (on study leave).
Principal Research Officer—H. E. Vivian, B.Sc.Agr.
Principal Research Officer—G. F. Walker, B.Sc., Ph.D.
Principal Research Officer—W. O. Williamson, B.Sc., Ph.D.
Senior Research Officer—S. M. Brisbane, B.A., B.Sc., A.M.T.C.
Senior Research Officer—H. Ellerton (at Bonython Research Laboratory, School of Mines, Adelaide).
Senior Research Officer—L. S. Williams, D.Phil., B.E.
Research Officer—K. M. Alexander, M.Sc., Ph.D.
Research Officer—G. M. Bruere, M.Sc.
Research Officer—H. R. Samson, B.Sc., Ph.D.
Research Officer—J. H. Taplin, B.Sc.(Hons.).
Senior Technical Officer—C. E. S. Davis, B.Sc. (Hons.).
Senior Technical Officer—K. Grant, B.Sc.
Senior Technical Officer—J. D. Wolfe.
Technical Officer—R. W. Cox, F.M.T.C.
Technical Officer—P. J. Darragh, B.Sc. (at Bonython Research Laboratory, School of Mines, Adelaide).
Technical Officer—R. R. Hughan.
Technical Officer—Mrs. M. Lawrence, B.Sc.
Technical Officer—Miss B. C. Terrell, B.Sc.
Technical Officer—J. Wardlaw, B.Sc.(Hons.).
Technical Officer—J. H. Weymouth, B.Sc.

Foundry Sands Section—

Senior Research Officer—H. A. Stephens, B.Sc.
Technical Officer—P. W. Goad, A.M.T.C.
Technical Officer—A. N. Waterworth, A.H.T.C.

Chemical Physics Section—

Senior Principal Research Officer—A. L. G. Rees, D.Sc., Ph.D.
Principal Research Officer—A. Walsh, M.Sc.Tech.
Principal Research Officer—J. L. Farrant, M.Sc.
Principal Research Officer—A. McL. Mathieson, B.Sc., Ph.D. (abroad).
Senior Research Officer—D. A. Davies, B.Sc.
Senior Research Officer—J. M. Cowley, M.Sc., Ph.D.
Senior Research Officer—J. D. Morrison, B.Sc., Ph.D.
Senior Research Officer—A. J. C. Nicholson, M.Sc., Ph.D.
Senior Research Officer—G. R. Hercus, M.Sc., D.Phil.
Senior Research Officer—J. B. Willis, M.Sc., Ph.D.
Research Officer—A. F. Moodie, B.Sc.
Research Officer—A. J. Hodge, B.Sc., Ph.D.
Research Officer—B. Dawson, M.Sc., Ph.D.
Research Officer—J. P. Shelton, M.Sc., A.R.S.M.
Research Officer—C. Billington, B.A.
Research Officer—C. K. Coogan, M.Sc., Ph.D.
Research Officer—J. O. Cope, M.Sc., Ph.D.
Research Officer—J. Fridrichsons, M.Sc.
Research Officer—A. C. Hurley, M.A., B.Sc., Ph.D.
Research Officer—A. F. Beecham, B.Sc.
Research Officer—J. C. Riviere, M.Sc. (on study leave).
Research Officer—J. V. Sullivan, M.Sc. (at University of Western Australia).
Research Officer—N. S. Ham, M.Sc. (on study leave).
Research Officer—P. Goodman, M.Sc.
Research Officer—W. C. T. Dowell, M.Sc.
Technical Officer—E. Cakanovskis, Dipl.Ing.

Physical Chemistry Section—

Senior Principal Research Officer—K. L. Sutherland, D.Sc., Ph.D.
Principal Research Officer—S. D. Hamann, M.Sc., Ph.D. (at Department of Chemical Engineering, University of Sydney).
Senior Research Officer—J. A. Barker, B.A., B.Sc.
Senior Research Officer—I. Brown, B.Sc.(Hons.).
Senior Research Officer—W. E. Ewers, M.Sc.
Senior Research Officer—V. A. Garten, D.Sc.
Senior Research Officer—W. W. Mansfield, B.Sc. (Hons.).
Senior Research Officer—E. A. Swinton, B.Sc. (Hons.).
Senior Research Officer—D. E. Weiss, B.Sc.
Senior Research Officer—M. E. Winfield, M.Sc., Ph.D. (abroad).
Research Officer—H. G. David, B.Sc. (at Department of Chemical Engineering, University of Sydney).
Research Officer—A. Ewald, B.Sc., Ph.D. (at Department of Chemical Engineering, University of Sydney).
Research Officer—E. P. Purser, B.Sc.(Hons.).
Research Officer—J. Bowler Reed, B.Sc., Ph.D.
Research Officer—H. P. Rothbaum, B.A., M.Sc.
Senior Technical Officer—L. F. Evans, D.S.M.B.
Technical Officer—W. Fock, B.Sc.
Technical Officer—M. Linton, B.Sc.
Technical Officer—R. McNeill, A.S.T.C.
Technical Officer—F. Meadows, B.Sc.
Technical Officer—M. Ross, Ing.
Technical Officer—F. Smith.

Organic Chemistry Section—

Senior Principal Research Officer—H. H. Hatt, D.Sc., Ph.D.
Senior Principal Research Officer—J. R. Price, M.Sc., D.Phil. (abroad).
Principal Research Officer—W. Zimmermann, D.Ing.
Senior Research Officer—C. C. J. Culvenor, Ph.D., D.Phil.
Senior Research Officer—J. S. Fitzgerald, M.Sc., Ph.D.
Senior Research Officer—K. E. Murray, B.Sc. (Hons.).
Research Officer—C. S. Barnes, M.Sc., Ph.D.
Research Officer—R. B. Bradbury, B.Sc., Ph.D.
Research Officer—W. D. Crow, M.Sc., Ph.D.
Research Officer—L. K. Dalton, A.S.T.C.
Research Officer—H. Duewell, B.Sc., Ph.D.
Research Officer—E. Gellert, Ph.D.
Research Officer—N. C. Hancox, M.Sc.
Research Officer—J. A. Lamberton, B.Sc., Ph.D.
Research Officer—R. J. L. Martin, M.Sc., Ph.D.
Technical Officer—W. G. Austin, Dip.App.Chem.
Technical Officer—G. B. Carter, Dip.App.Chem.
Technical Officer—P. M. Hunter, A.S.T.C.
Technical Officer—M. Michael, M.Sc.
Technical Officer—A. H. Redcliffe, Dip.Anal.Chem. M.U.
Technical Officer—R. Schoenfeld, B.Sc.
Technical Officer—L. W. Smith, B.Sc.
Technical Officer—A. Z. Szumer (on study leave).

Chemical Engineering Section—

Principal Research Officer—R. W. Urie, B.Sc., S.M.
Senior Research Officer—T. J. Birch, B.Sc.
Senior Research Officer—J. D. Blackwood, B.Sc., Ph.D.

Research Officer—K. Hall, M.Sc.
Research Officer—O. G. Ingles, M.Sc.
Research Officer—P. Terry, B.Sc.(Hons.), M.Chem. Eng.
Research Officer—A. B. Whitehead, B.Sc.
Senior Technical Officer—J. B. Ross, B.Sc., A.M.T.C.
Senior Technical Officer—D. H. Trethewey, A.M.T.C., A.I.C.E.
Senior Technical Officer—B. W. Wilson, M.Sc.
Technical Officer—P. Casamento, D.Ing.
Technical Officer—G. Evans, B.Sc.
Technical Officer—F. McGrory, B.Sc.
Technical Officer—C. W. Thomas, B.Sc.
Sectional Draughtsman—C. Simpson.

At Division of Electrotechnology, Sydney—
Research Officer—H. K. Welsh, B.Sc. (seconded).

Library—
Librarian—Miss B. M. Brown, B.Sc.

17. IRRIGATION RESEARCH STATION (MURRUMBIDGEE IRRIGATION AREAS).

(Head-quarters: Griffith, New South Wales.)

Officer-in-charge—E. S. West, B.Sc., M.S.
Research Officer (Plant Physiology)—C. T. Gates, B.Sc.Agr.
Technical Officer—Ir. D. Bouma.
Technical Officer—Ir. H. Groenewegen.
Librarian—Miss M. Russell.

Seconded to New South Wales Department of Agriculture—
Senior Research Officer—D. V. Walters, M.Agr.Sc.
Research Officer—Mrs. J. Tully, B.Sc., Ph.D.

18. LAND RESEARCH AND REGIONAL SURVEY SECTION.

(Head-quarters: Canberra, Australian Capital Territory.)

At Head-quarters, Canberra—
Officer-in-charge—C. S. Christian, B.Sc.Agr., M.S.
Technical Secretary—Miss M. Mills, B.Sc.
Principal Research Officer—E. Phillis, Ph.D., D.Sc.
Research Officer—R. O. Slatyer, B.Sc.(Agric.).

At Kimberley Research Station, Western Australia—
Research Officer—L. C. Lee, B.Agr.Sc.
Technical Officer—E. C. B. Langfield.
Technical Officer—A. L. Chapman, B.Agr.Sc.

At Katherine Research Station, Northern Territory—
Research Officer—W. Arndt, B.Sc.Agr.
Research Officer—F. H. Kleinschmidt, B.Sc.Agr.
Technical Officer—L. J. Phillips, Q.D.D.M.
Technical Officer—W. R. Stern, B.Sc.Agr.
Technical Officer—L. J. McHugh, B.Sc.Agr.

At Alice Springs, Northern Territory—
Technical Officer—R. E. Winkworth, B.Sc.

Regional Survey, Canberra—
Senior Research Officer—G. A. Stewart, B.Agr.Sc.
Research Officer—R. A. Perry, B.Sc.
Research Officer—N. H. Speck, M.Sc.
Research Officer—J. R. Sleeman, B.Agr.Sc. (seconded from Division of Soils).
Research Officer—C. R. Twidale, M.Sc.
Technical Officer—M. Lazarides, Q.D.A.

Papua-New Guinea Resources Survey, Canberra—
Research Officer—S. J. Paterson, B.Sc.
Research Officer—H. A. Haantjens, Ing.Agr.
Research Officer—R. D. Hoogland, D.Sc.
Research Officer—B. W. Taylor, B.Sc.
Technical Officer—J. C. Saunders, B.Sc.Agr.
Technical Officer—Miss J. Bradley, B.Sc.

19. MATHEMATICAL INSTRUMENTS SECTION.

(Head-quarters: Department of Electrical Engineering, University of Sydney.)

Officer-in-charge—Professor D. M. Myers, B.Sc., D.Sc.Eng.
Research Officer—M. W. Allen, B.E.
Technical Officer—R. J. Keith, B.E., A.S.T.C.

20. DIVISION OF MATHEMATICAL STATISTICS.

(Head-quarters: University of Adelaide.)

At Head-quarters, Adelaide—
Chief—E. A. Cornish, D.Sc., B.Agr.Sc.
Senior Research Officer—A. T. James, M.Sc., Ph.D.
Research Officer—G. N. Wilkinson, B.Sc.
Technical Officer—M. L. Dudzinski, B.Sc.

At Division of Animal Health and Production, Sydney—
Principal Research Officer—Miss H. A. Newton Turner, B.Arch.
Research Officer—V. J. Bofinger, B.Sc.
Research Officer—Miss N. B. Hemingway, B.Sc.
Research Officer—Miss M. C. McKevett, B.A.

At Division of Animal Health and Production, Prospect, New South Wales—
Research Officer—H. A. David, B.Sc., Ph.D.

At Division of Building Research, Highett, Victoria—
Senior Research Officer—R. Birtwistle, B.Sc.
Research Officer—W. B. Hall, B.A.

At Coal Research Section, North Ryde, New South Wales—
Research Officer—A. G. L. Elliott, B.Sc.

At Division of Food Preservation and Transport, Homebush, New South Wales—
Senior Research Officer—G. G. Coote, B.A., B.Sc.
Research Officer—V. Chew, B.Sc.

At Division of Forest Products, Melbourne—
Principal Research Officer—E. J. Williams, B.Com., D.Sc.

At Division of Plant Industry, Canberra—
Principal Research Officer—G. A. McIntyre, B.Sc., Dip.Ed.

At Division of Plant Industry, Brisbane—
Research Officer—K. P. Haydock, B.Sc.

At Regional Pastoral Laboratory, Armidale, New South Wales—
Research Officer—P. F. May, B.Sc.Agr.

At University of Western Australia, Perth—
Research Officer—N. S. Stenhouse, B.Sc.

21. SECTION OF METEOROLOGICAL PHYSICS.

(Head-quarters: Station-street, Aspendale, Victoria.)

Officer-in-charge—C. H. B. Priestley, M.A., Sc.D.
Principal Research Officer—W. C. Swinbank, B.Sc.
Principal Research Officer—E. L. Deacon, B.Sc.
Principal Research Officer—F. A. Berson, Ph.D.
Senior Research Officer—R. J. Taylor, B.Sc.
Research Officer—I. C. Ilroy, B.Sc.
Research Officer—E. K. Webb, B.A., B.Sc.
Research Officer—F. K. Ball, B.Sc.
Research Officer—C. F. Barrett, M.Sc.
Research Officer—W. W. Moriarty, M.Sc.
Technical Officer—D. E. Angus, B.Sc.
Technical Officer—A. J. Troup, B.Sc.

22. Division of Metrology.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Chief—N. A. Esserman, B.Sc.
Technical Secretary—N. H. Winters, B.E.
Principal Research Officer—C. A. Gladman, B.Sc.(Eng.), A.C.G.I.
Principal Research Officer—G. A. Bell, B.Sc.
Principal Research Officer—C. F. Bruce, M.Sc.
Senior Research Officer—H. J. Ritter, Dr.rer.nat.-math.
Senior Research Officer—H. A. Ross, A.S.T.C.
Senior Research Officer—J. A. Macinante, B.E., A.S.T.C.
Senior Research Officer—M. J. Puttock, B.Sc.(Eng.).
Research Officer—Miss M. G. I. Pearce, M.Sc.
Research Officer—W. A. F. Cuninghame, B.E.
Research Officer—Miss M. C. Dive, B.Sc.
Research Officer—Miss P. M. Yelland.
Research Officer—Miss M. M. Douglas, B.Sc.
Research Officer—N. J. C. Peres, M.Sc.
Research Officer—J. Waldersee, B.Sc.
Research Officer—B. S. Thornton, M.Sc.
Research Officer—I. F. Mayer, B.Sc., B.E.
Principal Technical Officer—R. H. Furniss, A.S.T.C.
Senior Technical Officer—R. Springer.
Senior Technical Officer—R. J. Ellis, B.E.
Technical Officer—D. H. Fox.
Technical Officer—G. W. Gore, A.S.T.C.
Technical Officer—E. Grunwald.
Technical Officer—J. C. Kelly, B.Sc.
Technical Officer—E. J. Thwaite, B.Sc.
Technical Officer—S. A. Dunk, B.E., A.S.T.C.
Technical Officer—P. Albrecht, Dipl.Ing.

23. Mineragraphic Investigations.

(Head-quarters: University of Melbourne.)

Senior Principal Research Officer—A. B. Edwards, D.Sc., Ph.D., D.I.C.
Senior Research Officer—G. Baker, M.Sc.
Research Officer—J. McAndrew, B.Sc., Ph.D.

24. National Standards Laboratory.

(The services shown hereunder are common to the Divisions of Metrology, Electrotechnology, and Physics, housed in the Laboratory.)

Clerical—
  Chief Clerk—W. J. Gillespie, F.A.S.A., A.C.I.S., J.P.
  Accountant—F. J. Whitty.

Library—
  Senior Librarian—Miss M. McKechnie, B.A.
  Librarian—Miss J. M. Cook, B.A.
  Librarian—Miss C. Gough.
  Librarian—Mrs. M. P. Fowler.

Workshops—
  Engineer-in-charge—J. Hanna.

Drawing Office—
  Chief Draughtsman—B. H. P. Cresswell, Dip.Mech. Eng.
  Sectional Draughtsman, Grade II.—J. Coles.
  Draughtsman, Grade II.—R. Riches.
  Draughtsman, Grade II.—R. Partridge.
  Draughtsman, Grade II.—J. Weir.

25. Oenological Research.

(Head-quarters: Waite Agricultural Research Institute, Adelaide.)

Principal Research Officer—J. C. M. Fornachon, M.Sc., B.Ag.Sc.
Research Officer—B. C. Rankine, M.Sc.

26. Ore-dressing Investigations.

(Head-quarters: University of Melbourne.)

Officer-in-charge—Associate Professor H. H. Dunkin, B.Met.E.
Principal Research Officer—K. S. Blaskett, B.E.
Research Officer—S. B. Hudson, M.Sc.
Research Officer—J. T. Woodcock, B.Met.E., M.Eng. Sc.
Senior Technical Officer—F. D. Drews.

27. Physical Metallurgy Section.

(Head-quarters: University of Melbourne.)

Officer-in-charge (Honorary)—Professor J. Neill Greenwood, D.Sc., M.Met.E.
Principal Research Officer—H. W. Worner, D.Sc., M.Sc.
Senior Research Officer—R. C. Gifkins, B.Sc.
Research Officer—A. E. Jenkins, Ph.D., M.Eng.Sc.
Research Officer—J. W. Suiter, M.Sc.
Technical Officer—J. A. Corbett.
Technical Officer—G. N. Boyd, A.M.T.C.

28. Division of Physics.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Administration—
  Chief—G. H. Briggs, D.Sc., Ph.D.
  Technical Secretary—D. S. Woodward.

Heat—
  Principal Research Officer—A. F. A. Harper, M.Sc.
  Senior Research Officer—W. R. G. Kemp, B.Sc.
  Senior Research Officer—R. G. Wylie, M.Sc., Ph.D.
  Senior Research Officer—G. K. White, M.Sc., D.Phil.
  Senior Research Officer—P. G. Klemens, M.Sc., D.Phil.
  Research Officer—W. A. Caw, B.Sc.
  Research Officer—Miss R. Scott, B.Sc. (on leave abroad).
  Research Officer—N. H. Westwood, B.Sc.
  Research Officer—J. Middlehurst, B.Sc.
  Technical Officer—J. V. McAllan, B.Sc.
  Technical Officer—Miss I. M. Beavis, B.Sc., Dip.Ed.
  Technical Officer—J. K. Braithwaite, A.M.T.C.

Light—
  Principal Research Officer—R. G. Giovanelli, D.Sc.
  Senior Research Officer—W. H. Steel, B.A., B.Sc., Dr.èsSc.
  Research Officer—K. A. Wright, B.Sc.
  Research Officer—W. R. Bleven, M.Sc., Dip.Ed.
  Research Officer—Associate Professor G. H. Godfrey, M.A., B.Sc. (part-time).
  Research Officer—C. E. Coulman, B.Sc.
  Technical Officer—W. J. Brown, A.S.T.C.

Solar Physics—
  Research Officer—J. T. Jefferies, M.A., B.Sc.
  Research Officer—R. E. Loughhead, M.Sc.
  Technical Officer—V. R. Burgess, A.S.T.C.

Electronics—
  Research Officer—A. F. Young, M.Sc.

29. Plant Fibre Section.

(Head-quarters: Graham-road, Highett, Victoria.)

Officer-in-charge—W. L. Greenhill, M.E.
Senior Research Officer—Miss J. F. Couchman, B.Sc.
Senior Research Officer—G. W. Lanigan, M.Sc.
Research Officer—W. Shepherd, B.Sc., B.Ag.Sc.
Senior Technical Officer—J. de Freitas, F.M.T.C.
Technical Officer—C. J. Brady, B.Ag.Sc.
Technical Officer—J. A. Milne, A.M.T.C.

30. Division of Plant Industry.

(Head-quarters: Canberra, A.C.T.)

Administration—

Chief—O. H. Frankel, D.Sc., D.Agr., F.R.S.
Technical Secretary—A. Shavitsky, B.Agr.Sc.
Divisional Engineer—G. L. Brown, B.Sc.
Librarian—Miss J. Humphreys, B.A., Dip.Ed. (half-time).
Chief Clerk—K. J. Prowse (half-time).
Deputy Chief Clerk—D. Banyard (half-time).
Accountant—L. G. Peres, B.Ec. (half-time).

Group 1—Botany and Genetics—

Leader—O. H. Frankel, D.Sc., D.Agr., F.R.S.
Deputy Leader—C. Barnard, D.Sc.

Genetics and Cytology, Canberra—
Senior Research Fellow—M. J. D. White, D.Sc.
Principal Research Officer—F. H. W. Morley, B.V.Sc., Ph.D.
Research Officer—R. D. Brock, M.Agr.Sc.
Research Officer—H. Daday, M.Sc.
Research Officer—C. I. Davern, B.Agr.Sc.
Technical Officer—Miss R. Stephens, B.Sc.
Technical Officer—J. W. Peak.

Structural Botany, Canberra—
Principal Research Officer—C. Barnard, D.Sc.

Plant Introduction, Canberra—
Principal Research Officer—W. Hartley, B.A., Dip.Ag.
Research Officer—C. A. Neal-Smith, B.Agr.Sc. (abroad).
Research Officer—N. J. Ketellapper, Ph.D., B.Sc.
Technical Officer—R. J. Williams, B.Sc.
Technical Officer—Miss D. E. Johns, B.Sc.

Herbarium, Canberra—
Senior Research Officer—Miss N. T. Burbidge, M.Sc. (abroad).

Plant Introduction, Queensland—
Principal Research Officer—J. F. Miles, B.Agr.Sc.
Research Officer—E. H. Kipps, B.Sc.

Plant Introduction, Western Australia.
Senior Research Officer—E. T. Bailey, B.Sc.
Technical Officer—N. B. Gayfer, D.D.A.

Microbiology, Canberra—
Senior Research Fellow—K. O. Muller, D.Phil.
Research Officer—J. H. E. Mackay, B.Sc.Agr.
Research Officer—Miss K. Helms, M.Sc. (abroad).
Technical Officer—Miss J. Friend, B.Sc.Agr.

Soil Microbiology, Canberra—
Senior Research Fellow—P. S. Nutman, B.Sc., Ph.D.
Senior Research Officer—F. W. Hely, M.Sc.Agr., M.S.
Research Officer—S. M. Bromfield, Ph.D., M.Agr.Sc.
Research Officer—F. J. Bergersen, M.Sc.
Technical Officer—J. Brockwell, D.D.A.

Disease Control, Canberra—
Principal Research Officer—H. R. Angell, O.B.E., Ph.D., B.Sc.Agr., M.S.

Fruit Investigations, Hobart—
Principal Research Officer—D. Martin, M.Sc.
Research Officer—T. L. Lewis, B.Sc.
Technical Officer—J. Cerny, Ph.D.

Fruit Investigations, Queensland—
Principal Research Officer—L. A. Thomas, M.Sc.

Tobacco Investigations, Canberra—
Principal Research Officer—A. V. Hill, M.Sc.Agr.
Research Officer—D. C. Wark, M.Agr.Sc.
Technical Officer—M. Mandryk, B.Sc.Agr.

Tobacco Investigations, Ayr, Queensland—
Research Officer—W. J. Lovett, B.Agr.Sc.

Group 2—Chemistry and Physiology—

General Chemistry, Canberra—
Senior Research Officer—C. H. Williams, M.Sc.
Senior Research Officer—A. Steinbergs, Nut. Chem.(Riga).
Research Officer—D. J. David, M.Sc.

Soil Chemistry, Melbourne—
Research Officer—L. H. P. Jones, Ph.D., B.Sc.Agr.

Plant Nutrition, Canberra—
Principal Research Officer—A. J. Anderson, B.Sc.Agr.
Senior Research Officer—K. D. McLachlan, B.Sc.Agr., B.Com.
Research Officer—D. Spencer, Ph.D., B.Sc.
Research Officer—J. V. Possingham, B.Agr.Sc.
Research Officer—J. F. Loneragan, Ph.D., B.Agr.Sc.

Plant Toxicology, Canberra—
Principal Research Officer—C. G. Greenham, M.Sc.

Plant Biochemistry, Canberra—
Research Officer—P. L. Goldacre, B.Sc., Ph.D.

Plant Biochemistry, Melbourne—
Research Officer—C. A. Appleby, B.Sc.

Tobacco Biochemistry, Canberra—
Senior Research Officer—R. Johanson, M.Sc.
Technical Officer—P. Macnicol, B.Sc.

Organic Chemistry, Canberra—
Research Officer—W. Bottomley, B.Sc., Ph.D.
Technical Officer—P. I. Mortimer, B.Sc.

Plant Physiology, Canberra—
Principal Research Officer—L. A. T. Ballard, Ph.D., M.A., M.Ag.Sc.
Research Officer—J. A. Zwar, M.Agr.Sc.
Research Officer—A. H. C. G. Rijven, Ph.D., B.Sc.

Tobacco Physiology, Canberra—
Research Officer—J. Calvert, D.Sc.

Crop Physiology, Canberra—
Principal Research Officer—R. F. Williams, M.Sc.

Group 3—Agrostology and Agronomy (Southern and Western Australia)—

Leader—R. M. Moore, M.Sc.Agr.

At Canberra—

Agrostology and Agronomy—
Senior Research Officer—W. D. Andrew, M.Agr.Sc.
Research Officer—W. M. Willoughby, B.Sc.Agr.
Research Officer—R. S. J. Lipsett, B.Agr.Sc.
Technical Officer—J. D. Williams, D.D.A.

Dickson Experiment Station—
Technical Officer—R. J. Hutchings, D.D.A.

Ecology—
Senior Principal Research Officer—R. M. Moore, M.Sc.Agr.
Research Officer—C. W. E. Moore, B.Agr.Sc.
Research Officer—L. F. Myers, B.Agr.Sc. (abroad).
Research Officer—E. F. Biddiscombe, M.Agr.Sc.
Technical Officer—J. A. Robertson, Q.D.D.M.

At Regional Pastoral Laboratory, Armidale, New South Wales—

Native Pastures—
Principal Research Officer—R. Roe, B.Sc.Agr. (abroad).
Research Officer—J. E. Begg, B.Sc.Agr.
Technical Officer—B. E. Mottershead, B.Sc.

Sown Pastures—
Research Officer—E. J. Hilder, B.Agr.Sc.
Technical Officer—J. A. Thompson, B.Sc.(For.).

Plant Nutrition—
Research Officer—K. Spencer, B.Sc.Agr.
Technical Officer—N. J. Barrow, B.Sc.Agr.

Ecology—
Senior Research Officer—R. W. Jessup, M.Sc.
Technical Officer—F. R. Gnauck, B.Sc.

Chemistry—
Technical Officer—J. R. Freney, B.Sc.

At Regional Pastoral Laboratory, Deniliquin, New South Wales—
Officer-in-charge—R. W. Prunster, B.Sc. (Agric.).

Agronomy—
Research Officer—K. P. Barley, M.Agr.Sc.

Ecology—
Research Officer—O. B. Williams, M.Agr.Sc.

Hydrology—
Research Officer—J. R. Philip, B.C.E.

Production and Utilization—
Research Officer—R. N. J. Bickerdike, B.A.

At Mitchell Laboratory, Trangie, New South Wales—
Ecology—
Research Officer—A. A. Holland, M.Sc.Agr.

At Irrigation Research Station, Griffith, New South Wales—
Ecology—
Research Officer—E. Levi, M.Sc.

At Waite Institute, Adelaide, South Australia—
Oil Crop Investigations—
Senior Research Officer—B. Horowitz, D.Agr.Sc.

At Institute of Agriculture, Perth, Western Australia—
Plant Nutrition—
Principal Research Officer—R. C. Rossiter, D.Sc.Agr.
Research Officer—P. G. Ozanne, B.Agr.Sc.
Technical Officer—R. J. Pack, Q.D.A.

Agronomy—
Research Officer—A. W. Humphries, B.Sc.(Agr.).
Technical Officer—D. J. Kirton, B.Sc.(Agr.).

Chemistry—
Technical Officer—T. Shaw, B.Sc.

At Glen Lossie Field Station, Kojonup, Western Australia—
Research Officer—E. R. Watson, B.Sc.(Agric.), M.Sc.
Technical Officer—J. Beresford, D.D.A.
Technical Officer—P. Lapins, M.Agr.Sc.

At University of Queensland, Brisbane—
Ecology—
Senior Research Officer—L. J. Webb, M.Sc.

Group 4—Agrostology and Agronomy (Queensland)—
Leader—J. Griffiths Davies, B.Sc., Ph.D.

At Plant and Soils Laboratory, Brisbane—
Associate Chief—J. Griffiths Davies, B.Sc., Ph.D.

Agrostology—
Principal Research Officer—T. B. Paltridge, B.Sc.

Agronomy—
Principal Research Officer—W. W. Bryan, M.Sc.Agr.
Research Officer—S. G. Gray, B.Sc.Agr.
Technical Officer—B. B. Brett, B.Agr.Sc., Q.D.A.

Cattle Pastures—
Senior Research Officer—N. H. Shaw, B.Sc.Agr.
Technical Officer—T. W. Elich, Dip.Col.Agr.

Plant Nutrition—
Senior Research Officer—C. S. Andrew, B.Agr.Sc.
Research Officer—R. G. Coleman, Ph.D., B.Sc.Agr., D.I.C.
Technical Officer—W. H. J. Pieters, Dip.Col.Agr.

Plant Chemistry—
Research Officer—M. P. Hegarty, Ph.D., M.Sc.
Technical Officer—Miss P. M. Thorne, B.Sc.

Ecology—
Senior Research Officer—D. E. Coaldrake, M.Sc.
Technical Officer—W. F. Ridley, B.Sc.

Genetics—
Principal Research Officer—E. M. Hutton, D.Sc., B.Agr.Sc.

Legume Bacteriology—
Principal Research Officer—D. O. Norris, D.Sc. (Agric.).

At Cooper Laboratory, Lawes, Queensland—
Research Officer—W. J. Bisset, B.Agr.Sc.
Technical Officer—R. Milford, B.Sc., Q.D.A.
Technical Officer—G. A. Taylor, Q.D.A.
Technical Officer—H. Kiers, Dip.Col.Agric.

31. DIVISION OF RADIOPHYSICS.

(Head-quarters: University of Sydney.)

Chief—E. G. Bowen, O.B.E., M.Sc., Ph.D.

Assistant Chief—J. L. Pawsey, F.R.S., M.Sc., Ph.D.

Technical Secretary—A. J. Higgs, B.Sc.

Assistant Technical Secretary—L. L. McCready, B.Sc., B.E.

Cloud and Rain Physics—
Principal Research Officer—J. Warner, B.Sc., B.E.
Principal Research Officer—J. G. Bolton, B.A.
Principal Research Officer—P. Squires, M.A.
Principal Research Officer—E. J. Smith, M.B.E., B.Sc.(Eng.).
Research Officer—N. R. Labrum, B.Sc.
Research Officer—E. E. Adderley, B.Sc.
Research Officer—E. K. Bigg, M.Sc., Ph.D.
Research Officer—S. Twomey, M.Sc.
Research Officer—J. M. Telford, B.Sc.
Research Officer—J. S. Turner, M.Sc.

Radio Astronomy—
Principal Research Officer—J. H. Piddington, M.Sc., B.E., Ph.D.
Principal Research Officer—B. Y. Mills, B.Sc., M.E.
Senior Research Officer—F. J. Kerr, M.Sc., M.A.
Senior Research Officer—R. N. Bracewell, B.Sc., B.E., Ph.D.
Senior Research Officer—J. P. Wild, M.A.
Research Officer—S. F. Smerd, B.Sc.
Research Officer—C. A. Shain, B.Sc.
Research Officer—J. A. Roberts, M.Sc., Ph.D.
Research Officer—R. X. McGee, B.Sc.
Research Officer—B. R. Robinson, M.Sc.
Research Officer—J. A. Warburton, B.Sc.
Research Officer—R. F. Mullaly, M.Sc.
Research Officer—A. W. L. Carter, B.Sc.
Senior Technical Officer—K. V. Sheridan, B.Sc.
Senior Technical Officer—J. V. Hindman.
Senior Technical Officer—K. R. McAlister, A.S.T.C.
Senior Technical Officer—G. J. Stanley, A.S.T.C.
Technical Officer—J. D. Murray, B.Sc.(Eng.).
Technical Officer—A. G. Little, A.S.T.C.
Technical Officer—O. B. Slee, A.S.T.C.
Technical Officer—H. R. Harant, A.S.T.C.
Technical Officer—M. M. Komesaroff, B.Sc.

Radio Navigation—
Senior Research Officer—H. C. Minnett, B.Sc., B.E.
Research Officer—G. A. Day.
Research Officer—D. E. Yabsley, B.Sc., B.E.
Research Officer—F. F. Gardner, B.Sc., B.E.
Senior Technical Officer—P. T. Hedges, A.S.T.C.
Technical Officer—R. S. Joseph, A.S.T.C.
Technical Officer—I. K. Harvey, A.S.T.C.

Physics of Semi-conductors—
Senior Research Officer—B. F. C. Cooper, B.Sc., B.E.
Research Officer—L. W. Davies, B.Sc., D.Phil.
Research Officer—D. Haneman, M.Sc.
Senior Technical Officer—F. C. Tonking, A.S.T.C.

Mathematical Computation—
Principal Research Officer—T. Pearcey, B.Sc.
Principal Research Officer—M. Beard, B.Sc., B.E.
Research Officer—G. W. Hill, B.Sc.
Research Officer—B. J. J. McHugh, B.Sc.
Technical Officer—R. T. H. Bowles, A.M.T.C.

Test Room—
Senior Technical Officer—G. A. Wells, A.S.T.C.
Technical Officer—T. E. Cousins, A.S.T.C.

Engineering Services—
Chief Draughtsman—F. M. Carter.
Draughtsman, Grade 2—H. F. Peddie, A.S.T.C.
Draughtsman, Grade 2—J. R. Morris.

Officers Abroad—
Principal Research Officer—W. N. Christiansen, D.Sc.
Research Officer—E. R. Hill, M.Sc.
Research Officer—N. H. Fletcher, B.Sc., M.A.

32. RADIO RESEARCH BOARD.

(Head-quarters: University of Sydney.)

Chief Scientific Officer—D. F. Martyn, D.Sc., Ph.D., A.R.C.S., F.R.S.
Principal Research Officer—G. H. Munro, D.Sc.
Senior Research Officer—W. L. Price, B.Sc. (part-time).
Research Officer—J. A. Harvey, B.Sc.
Research Officer—R. A. Duncan, B.Sc.
Technical Officer—L. H. Heisler, B.Sc.
Technical Officer—H. P. Hirschl, A.S.T.C.
Technical Officer—R. B. White, B.E.

33. DIVISION OF SOILS.

(Head-quarters: Waite Agricultural Research Institute, Adelaide.)

At Adelaide—

Administration—
Chief—J. K. Taylor, B.A., M.Sc., B.Sc.Agr.
Senior Clerical Officer—F. W. Blanksby.

Soil Survey and Pedology Section—
Senior Principal Research Officer—C. G. Stephens, D.Sc.
Senior Research Officer—K. H. Northcote, B.Ag.Sc.
Senior Research Officer—G. Blackburn, B.Ag.Sc.
Research Officer—E. A. Jackson, B.Ag.Sc.
Research Officer—C. B. Wells, B.Ag.Sc.
Research Officer—G. F. U. Baker, B.Sc.
Research Officer—Ir. C. J. de Mooy.
Sectional Draughtsman—P. D. Hooper.

Soil Chemistry Section—
Principal Chemist—C. S. Piper, D.Sc.
Principal Research Officer—A. C. Oertel, M.Sc.
Senior Research Officer—R. E. Shapter, A.A.C.I.
Senior Research Officer—J. T. Hutton, B.Sc., A.S.A.S.M.
Research Officer—H. C. T. Stace, B.Sc.
Research Officer—B. M. Tucker, B.Sc.
Research Officer—R. S. Beckwith, B.Sc.
Research Officer—M. Raupach, M.Sc.
Technical Officer—A. R. P. Clarke, A.S.A.S.M.
Technical Officer—R. M. McKenzie, A.S.A.S.M.
Technical Officer—R. D. Bond, A.S.A.S.M.

Soil Physics and Mechanics Section—
Senior Principal Research Officer—T. J. Marshall, M.Ag.Sc., Ph.D.
Senior Research Officer—G. D. Aitchison, M.E. (at University of Melbourne).
Research Officer—K. Norrish, M.Sc., Ph.D.
Research Officer—J. P. Quirk, B.Sc.Agr., Ph.D.
Research Officer—C. G. Gurr, B.Sc.
Research Officer—J. W. Holmes, B.Sc.
Research Officer—E. W. Radoslovich, M.Sc. (abroad).
Research Officer—D. S. McIntyre, M.Sc.
Technical Officer (temporary)—Mrs. L. E. R. Rogers, M.Sc.

Soil Microbiology Section—
Principal Research Officer—R. J. Swaby, M.Sc., M.Ag.Sc., Ph.D.
Research Officer—J. R. Harris, M.Sc.
Research Officer—J. N. Ladd, B.Sc.
Technical Officer—D. Bockman, B.Sc.Agr.

At Brisbane—

Soil Survey and Pedology Section—
Principal Research Officer—G. D. Hubble, B.Ag.Sc.
Research Officer—G. G. Beckmann, B.Sc.
Research Officer—W. H. Litchfield, B.Sc.Agr.
Technical Officer—C. H. Thompson, Q.D.A.

Soil Physics—
Research Officer—G. B. Stirk, B.Sc.
Technical Officer—R. E. Prebble, B.Sc.

Soil Chemistry—
Senior Research Officer—A. E. Martin, B.Sc., F.R.I.C.
Research Officer—J. E. Cox, B.Sc.
Technical Officer—R. Reeve, Dip.Ind.Chem.
Technical Officer—H. J. Beatty, Dip.Ind.Chem.

At Canberra—

Soil Survey and Pedology Section—
Principal Research Officer—B. E. Butler, B.Sc.Agr.
Senior Research Officer—R. Brewer, B.Sc.
Research Officer—D. C. van Dijk, Ing.Agr., D.Sc.
Research Officer—J. R. Sleeman, B.Ag.Sc. (seconded to Land Research and Regional Survey Section).
Research Officer—Ir. T. Talsma.

Soil Chemistry—
Senior Technical Officer—A. D. Haldane, B.Sc.

Soil Physics—
Technical Officer—A. V. Blackmore, B.Sc.

At Deniliquin—

Soil Survey and Pedology Section—
Research Officer—H. M. Churchward, B.Sc.Agr.
Research Officer—T. Poutsma, B.Sc.Agr.

At Hobart—

Soil Survey and Pedology Section—
Senior Research Officer—K. D. Nicholls, B.Ag.Sc., B.Sc. (abroad).
Research Officer—G. M. Dimmock, B.Sc.
Research Officer—J. Loveday, B.Ag.Sc.

Soil Chemistry—
Technical Officer—A. M. Graley, B.Sc.

At Perth—

Soil Survey and Pedology Section—
Research Officer—M. J. Mulcahy, B.Sc.
Research Officer—L. W. Pym, B.Sc.Agr.
Research Officer—W. M. McArthur, B.Sc.
Technical Officer—E. Bettenay, B.Sc.Agr.

Soil Chemistry—
Research Officer—A. G. Turton, B.Sc.
Technical Officer—F. J. Hingston, B.Sc.

34. Division of Tribophysics.

(Head-quarters: University of Melbourne.)

Chief—W. Boas, D.Ing., M.Sc.
Principal Research Officer—M. F. R. Mulcahy, D.Phil., M.Sc., A.G.Inst.Tech.
Senior Research Officer—L. M. Clarebrough, B.Met.E., M.Eng.Sc.
Senior Research Officer—M. E. Hargreaves, Ph.D., B.Met.E.
Senior Research Officer—J. K. Mackenzie, Ph.D., B.A.(Hons.), B.Sc.
Senior Research Officer—A. J. W. Moore, Ph.D., B.Sc.
Research Officer—B. D. Cuming, M.Sc. (abroad).
Research Officer—A. J. Davis, B.Eng.
Research Officer—D. Mitchell, B.E.E.
Research Officer—J. F. Nicholas, B.A.(Hons.), B.Sc.
Research Officer—G. J. Ogilvie, Ph.D., B.Met.E., M.Eng.Sc.
Research Officer—M. J. Ridge, M.Sc.
Research Officer—J. V. Sanders, Ph.D., B.Sc.(Hons.).
Research Officer—Mrs. H. M. C. Sosnowsky, Ph.D.
Research Officer—J. A. Spink, B.Sc.
Research Officer—R. G. Vines, M.Sc. (abroad).
Research Officer—G. W. West, B.E.E., B.Sc.
Research Officer—J. E. Young, Ph.D., B.Sc.
Technical Officer—J. J. Batten, B.Sc.
Technical Officer—L. A. Bennett, B.Sc.
Technical Officer—G. Brinson, B.Sc.
Technical Officer—R. W. Coventry, B.Sc.
Technical Officer—G. R. Perger, F.M.T.C.
Technical Officer—R. G. Sherwood, A.M.T.C.
Technical Officer—W. J. McG. Tegart, B.Sc., A.M.T.C.

35. Tracer Elements Investigations.

(Head-quarters: Chemistry School, University of Melbourne.)

Principal Research Officer—T. H. Oddie, D.Sc.
Research Officer—A. M. Downes, M.Sc.
Research Officer—K. R. Lynn, B.Sc.

36. Wildlife Survey Section.

(Head-quarters: Canberra, Australian Capital Territory.)

Officer-in-charge—F. N. Ratcliffe, B.A.
Principal Research Officer—R. Carrick, B.Sc., Ph.D.
Sectional Secretary—F. N. Robinson, B.A.
Research Officer—A. L. Dyce, B.Sc.Agr.
Research Officer—G. M. Dunnet, B.Sc., Ph.D.
Research Officer—B. J. G. Marlow, B.Sc.
Technical Officer—R. Mykytowycz, D.V.M.

At Perth—
Senior Research Officer—D. L. Serventy, B.Sc., Ph.D.
Research Officer—J. H. Calaby.
Research Officer—E. H. M. Ealey, M.Sc.

At Albury, New South Wales—
Research Officer—K. Myers, B.Sc.
Research Officer—W. E. Poole, B.Sc.

At Griffith, New South Wales—
Senior Research Officer—H. J. Frith, B.Sc.Agr.

At Armidale, New South Wales—
Research Officer—B. V. Fennessy, B.Agr.Sc.
Technical Officer—E. J. Waterhouse, B.Sc.Agr.

At Hobart—
Technical Officer—I. C. R. Rowley, B.Sc.Agr.

37. Wool Textile Research Laboratories.

Senior Officer-in-charge—F. G. Lennox, D.Sc.

At Wool Textile Research Laboratory, Melbourne—

Biochemistry Unit, 343 *Royal-parade, Parkville, Victoria—*
Officer-in-charge—F. G. Lennox, D.Sc.
Laboratory Secretary—C. Garrow, B.Com., D.P.A., A.A.S.A.
Principal Research Officer—H. Lindley, B.A., Ph.D. (abroad).
Principal Research Officer—W. G. Crewther, M.Sc.
Senior Research Officer—T. A. Pressley, B.Sc.
Senior Research Officer—J. M. Gillespie, M.Sc.
Senior Research Officer—M. A. Jermyn, M.Sc., Ph.D.
Senior Research Officer—S. J. Leach, B.Sc.Tech., Ph.D.
Senior Research Officer—E. F. Woods, M.Sc., A.M.T.C.
Senior Research Officer—J. M. Swan, B.Sc., Ph.D.
Senior Research Officer—R. D. B. Fraser, Ph.D.
Research Officer—W. E. Savige, Ph.D.
Research Officer—E. O. P. Thompson, M.Sc., Dip.Ed., Ph.D.
Research Officer—J. P. E. Human, Ph.D.
Research Officer—D. H. Simmonds, M.Sc., Ph.D.
Research Officer—I. J. O'Donnell, M.Sc.
Research Officer—B. S. Harrap, Ph.D.
Research Officer—G. E. Rogers, M.Sc.
Research Officer—R. Thomas, B.Sc., Ph.D.
Research Officer—P. H. Springell, M.A., Ph.D.
Research Officer—J. A. McLaren, Ph.D.
Research Officer—Mrs. A. R. Thompson, M.Sc.
Technical Officer—B. McQuade, B.Sc.
Technical Officer—I. G. Stell, Dip.Sw.T.C.
Technical Officer—K. I. Wood, A.M.T.C.

At Wool Textile Research Laboratory, Sydney—

Physics and Engineering Unit, The Hermitage, 338 *Blaxland-road, Ryde, New South Wales—*
Officer-in-charge—V. D. Burgmann, B.Sc., B.E.
Technical Secretary—I. J. W. Bissett, M.Sc.
Principal Research Officer—N. F. Roberts, M.Sc.
Senior Research Officer—J. G. Downes, B.Sc.
Senior Research Officer—Mrs. K. R. Makinson, B.A.(Hons.), F.Inst.P.
Senior Research Officer—H. W. Holdaway, B.Sc., B.E.
Senior Research Officer—M. Feughelman, B.Sc., A.S.T.C.
Research Officer—M. Chaikin, B.Sc., Ph.D., Dip.Eng.
Research Officer—I. M. Stuart, M.Sc.
Research Officer—Miss V. Laws, M.Sc.
Research Officer—K. Baird, B.Sc.
Research Officer—J. F. P. James, M.Sc.
Technical Officer—Miss J. C. Griffiths, B.Sc., A.S.T.C.
Technical Officer—B. J. Rigby, A.S.T.C.
Technical Officer—A. R. Haly, B.Sc.
Technical Officer—A. G. Stutter, B.Sc.
Technical Officer—P. Nordon, B.Sc., A.S.T.C.

At Wool Textile Research Laboratory, Belmont, Geelong, Victoria—

Officer-in-charge—M. Lipson, B.Sc., Ph.D.
Technical Secretary—T. Topham, A.M.I.I.A., A.T.I.
Senior Research Officer—D. L. C. Jackson, B.Sc.
Senior Research Officer—G. W. Walls, B.Sc.
Research Officer—C. A. Anderson, B.Sc.
Research Officer—J. H. Bradbury, M.Sc., Ph.D. (abroad).
Research Officer—J. Delmenico, B.Sc.
Research Officer—A. Gray, M.Sc.
Research Officer—D. R. Miller, M.Sc.
Research Officer—J. R. McPhee, B.Sc. (abroad).
Research Officer—C. H. Nicholls, B.Sc., Ph.D.
Research Officer—D. S. Taylor, B.A., B.Sc. (abroad).
Technical Officer—Miss R. J. Hope, A.G.Inst.Tech.
Technical Officer—P. R. Strutt, B.Sc.
Technical Officer—G. C. West, A.G.Inst.Tech.

XXXIV. PUBLISHED PAPERS.

The following papers have been published during the year:—

1. Animal Genetics Section.

Fraser, A. S., *and* May, T. (1953).—Growth of the mouse coat. II. Effect of sex and pregnancy. *Aust. J. Biol. Sci.* 6: 645-56.

Rendel, J. M. (1953).—Heterosis. *Amer. Nat.* 88: 129-38.

Rendel, J. M. (1954).—Inheritance of birthcoat in a flock of improved Welsh Mountain sheep. *Aust. J. Agric. Res.* 5: 297-304.

Sobey, W. R. (1954).—The inheritance of antibody response to tobacco mosaic virus in rabbits. *Aust. J. Biol. Sci.* 7: 111-17.

2. Division of Animal Health and Production.

Austin, C. R. (1953).—The growth of knowledge of mammalian fertilization. *Aust. Vet. J.* 29: 191-8.

Austin, C. R., *and* Braden, A. W. H. (1953).—An investigation of polyspermy in the rat and rabbit. *Aust. J. Biol. Sci.* 6: 674-92.

Austin, C. R., *and* Braden, A. W. H. (1953).—Polyspermy in mammals. *Nature.* 172: 82.

Austin, C. R., *and* Braden, A. W. H. (1954).—Induction and inhibition of the second polar division in the rat egg and subsequent fertilization. *Aust. J. Biol. Sci.* 7: 195-210.

Austin, C. R., *and* Braden, A. W. H. (1954).—Nucleus formation and cleavage induced in unfertilized rat eggs. *Nature.* 173: 999-1000.

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Beveridge, W. I.,* *and* Johnstone, I. L. (1953).—I. Sheath-rot, non-contagious posthitis or chronic ulceration of the prepuce of sheep. *Aust. Vet. J.* 29: 269-74.

Beveridge, W I., *and* Johnstone, I. L. (1953).—II. Experiments on the reproduction of the disease. *Aust. Vet. J.* 29: 329-36.

Beveridge, W. I., *and* Johnstone, I. L. (1954).—III. Curative effect of reduced food consumption or surgical measures. *Aust. Vet. J.* 30: 1-7.

Braden, A. W. H. (1953).—Distribution of sperms in the genital tract of the female rabbit after coitus. *Aust. J. Biol. Sci.* 6: 693-705.

Braden, A. W. H., *and* Austin, C. R. (1953).—The distribution of nucleic acids in rat eggs in fertilization and early segmentation. 2. Histochemical studies. *Aust. J. Biol. Sci.* 6: 665-73.

Braden, A. W. H., *and* Peterson, J. E.* (1953).—The persistence of endometrial cysts induced by oestrogen in guinea pigs. *Aust. J. Biol. Sci.* 6: 520-32.

Bull, L. B., Ratcliffe, F. N., *and* Edgar, G. (1953).—Myxomatosis: its use in the control of rabbit populations in Australia. Proc. 15th Int. Vet. Congr. 1: 396-9.

Bush, I. E., *and* Ferguson, K. A. (1953).—The secretion of the adrenal cortex in the sheep. *J. Endocrin.* 10: 1.

Daly, R. A., *and* Carter, H. B. (1954).—A method of fractionating raw fleece samples and some errors encountered in its use in experimental studies of fleece growth. *Aust. J. Agric. Res.* 5: 327-44.

Dick, A. T. (1953).—The control of copper storage in the liver of the sheep by inorganic sulphate and molybdenum. *Aust. Vet. J.* 29: 223-39.

Dick, A. T. (1953).—The influence of inorganic sulphate on the copper-molybdenum interrelationship in sheep. *Nature.* 172: 637-8.

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Durie, P. H. (1953).—The paramphistomes (*Trematoda*) of Australian ruminants. II. The life history of *Ceylonocotyle streptocoelium* (Fischoeder) Nasmark, and of *Paramphistomum ichikawai Fukui*. *Aust. J. Zool.* 1: 193-222.

Ferguson, K. A., *and* Boyden, S. V.† (1953).—Serological evidence of the antigenicity of ox anterior pituitary growth hormone in sheep. *J. Endocrin.* 9: 261-6.

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Forsyth, B. A. (1953).—Epidemiology studies on helminthosis of sheep in southern New South Wales. *Aust. Vet. J.* 29: 349-56.

Franklin, M. C. (1953).—Vitamin D requirements of sheep with special reference to Australian conditions. *Aust. Vet. J.* 29: 302-9.

Gallagher, C. H. (1954).—Investigations of the etiology of infectious ophthalmia of cattle. *Aust. Vet. J.* 30: 61-8.

Gordon, H. McL. (1953).—The epidemiology of helminthosis in sheep in winter-rainfall regions of Australia. I. Preliminary observations. *Aust. Vet. J.* 29: 337-48.

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Gregory, T. S. (1953).—A standardized rapid agglutination test for the quantitative estimation of *Brucella* antibody in milk. *J. Comp. Path.* 63: 171-8.

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* Institute of Animal Pathology, University of Cambridge.

* Western Australian Department of Agriculture.
† Pasteur Institute, Paris.
‡ Veterinary Research Station, Glenfield, New South Wales.
§ Department of Bacteriology, University of Melbourne.

Gregory, T. S. (1953).—Problems of infection and immunity in bovine brucellosis. *Proc. 15th Int. Vet. Congr.* 1:100-4.

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Hayman, R. H. (1953).—Studies in fleece-rot of sheep. *Aust. J. Agric. Res.* 4:430-68.

Heppel, L. A.,[†] Whitfield, P. R., *and* Markham, R.[†] (1954).—Exchange reactions involving dinucleotides and cyclic mononucleotides. *Biochem. J.* 56:111.

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Johnstone, I. L. (1954).—The blowfly problem. *Aust. Vet. J.* 30:113-5.

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Riek, R. F. (1953).—Studies on allergic dermatitis (Queensland itch) of the horse. Description, distribution, clinical symptoms and pathology of the disease. *Aust. Vet. J.* 29:185.

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Riek, R. F. (1954).—The influence of sodium salts on the closure of the oesophageal groove in calves. *Aust. Vet. J.* 30:29.

Roberts, F. H. S. (1953).—*Zygoribatula longiporosa* Hammer (Oribatai: Acarina), intermediate host of *Monieza benedeni* (Moniex 1879) (Anaplocephalidae: Cestoda) in Australia. *Aust. J. Zool.* 1:239-40.

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Roulston, W. J., Hitchcock, L. F., Turner, A. W., *and* Campbell, A. D. (1953).—The effect on cattle of long-continued cutaneous applications of DDT. *Aust. J. Agric. Res.* 4:469-80.

Skaller, F. (1954).—Studies on the assessment of egg production in poultry breeding investigations. I. The optimal period for recording first-year egg production. *Poult. Sci.* 33:29-35.

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Stewart, D. F. (1953).—Resistance to nematode infestation in sheep. Proc. 15th Int. Vet. Congr. 1: 417-21.

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Stewart, D. F., *and* Gordon, H. McL. (1953).—Studies on resistance of sheep to infestation with *Haemonchus contortus* and *Trichostrongylus* spp. 6. Influence of age and nutrition on resistance to *Trichostrongylus colubriformis*. *Aust. J. Agric. Res.* 4:340-8.

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Whitfeld, P. R. (1953).—The uptake of radioactive phosphorus by erythrocyte stages of *Plasmodium berghei* (Vincke and Lips.). *Aust. J. Biol. Sci.* 4:591-6.

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Whitlock, H. V. (1954).—Further observations on oesophageal tubes for drenching sheep. *Aust. Vet. J.* 30:100-4.

Yeates, N. T. M. (1953).—The effect of high air temperature on reproduction in the ewe. *J. Agric. Sci.* 43:199-203.

3. DIVISION OF BIOCHEMISTRY AND GENERAL NUTRITION.

Dawbarn, Mary C., *and* Hine, Denise C. (1954).—The determination of vitamin B_{12}-activity in the organs and excreta of sheep. I. Microbiological assay method. *Aust. J. Exp. Biol. Med. Sci.* 32:1-22.

Gray, F. V., Pilgrim, A. F., *and* Weller, R. A. (1953).—Conversion of plant nitrogen to microbial nitrogen in the rumen of the sheep. *Nature.* 172:347.

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Jarrett, I. G., *and* Potter, B. J. (1953).—Insulin tolerance and hypoglycaemic convulsions in sheep. *Aust. J. Exp. Biol. Med. Sci.* 31:311-8.

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[†] Agricultural Research Council, Plant Virus Research Unit, Molteno Institute, Cambridge

udbrook, W. V.,[*] Brockwell, J.,[†] *and* Riceman, D. S. (1953).—Bare-patch disease and associated problems in subterranean clover pastures in South Australia. *Aust. J. Agric. Res.* 4:403-14.

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'eirce, A. W. (1954).—Carotene and vitamin A in human fat. *Aust. Med. J.* 1:589.

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Veller, R. A., *and* Gray, F. V. (1954).—The passage of starch through the stomach of the sheep. *J. Exp. Biol.* 31:40.

4. Division of Building Research.

allantyne, E. R. (1954).—Rheological properties of certain joint-sealing compounds for concrete canal linings. C.S.I.R.O. Div. Build. Res. Tech. Pap. No. 2.

lakey, F. A. (1953).—Tests on prestressed concrete beams (letter to the Editor). *Constr. Rev.* 26 (8):17-9.

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ole, W. F., *and* Carthew, A. R. (1953).—The mineralogical composition of some Tasmanian clays. *Pap. Roy. Soc. Tasm.* 87:1-12.

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5. Coal Research Section.

Balme, B. E., *and* Brooks, J. D. (1953).—Kaolinite petrifactions in a New South Wales Permian coal seam. *Aust J. Sci.* 16:65.

Brooks, J. D., *and* Maher, T. P. (1954).—Direct titration of acidic groupings in coal. *Research, Lond.* 7:S30-1.

6. Commonwealth Research Station (Murray Irrigation Areas).

Giles, J. E., Neal-Smith, C. A., *and* Alexander, D. McE. (1953).—*Lathyrus ochrus* (L.)D.C. as a green manure crop under irrigation in the Murray valley area. *J. Aust. Inst. Agric. Sci.* 19:183-91.

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7. Cosmic Ray Research.

(Department of Physics, University of Tasmania.)

Jacklyn, R. M. (1954).—The barometer coefficient and air mass effects on cosmic rays at Macquarie Island. *Aust. J. Phys.* 7:315-21.

8. Dairy Research Section.

Conochie, J., *and* Wilkinson, R. W. (1953).—An occurrence of "oily" flavour in butter. *Aust. J. Dairy Tech.* 8:96.

Czulak, J. (1953).—Control of airborne bacteriophage by ultra-violet irradiation. Proc. 13th Int. Dairy Congr. 3:1094.

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Czulak, J., *and* Hammond, L. A. (1953).—Black spot in condensed milk. *Aust. J. Dairy Tech.* 8:66.

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King, N. (1953).—Influence of agitation during transport of milk fat. Proc. 13th Int. Dairy Congr. 2:208-11.

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[†] Division of Plant Industry, C.S.I.R.O.

9. DIVISION OF ELECTROTECHNOLOGY.

Clothier, W. K., *and* Medina, L. (1954).—A portable voltage transformer testing set. *Aust. J. Appl. Sci.* 5:145.

Dryden, J. S. (1953).—Dipole orientation in quinol clathrate compounds. *Trans. Faraday Soc.* 49: 1333.

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XXXV.—FINANCE.

1. EXPENDITURE.

The statement of expenditure from 1st July, 1953, to 30th June, 1954, is as follows:—

	£	£	£
(a) Salaries and contingencies			226,840*
(b) Investigations—			
(i) Animal Health and Production Problems		544,151	
Less contributions from—			
Wool Industry Fund	53,253		
Wool Research Trust Account	171,072		
Commonwealth Bank	2,066		
Australian Dairy Produce Board	3,566		
Australian Meat Board	23,733		
Australian Wool Board (Balance of old grants)	550		
Ian McMaster Bequest	1,448		
Alex. Fraser Memorial Fund	225		
Wm. McIlrath Fellowship	1,558		
C. P. Fairbairn	30		
Estate of Captain Ian McMaster	967		
Burdekin Bequest (Drought feeding)	1,700		
Special Revenue Funds—			
Burdekin Bequest	450		
Gilruth Plains Field Station	27,238		
		287,856	
			256,295
(ii) Biochemistry and General Nutrition Problems		92,528	
Less contributions from—			
Wool Research Trust Account	32,938		
Wool Industry Fund	1,716		
Australian Wool Board (Balance of old grants)	178		
		34,832	
			57,696
(iii) Plant Problems—Division of Plant Industry		478,158	
Less contributions from—			
Wool Industry Fund	10,048		
Wool Research Trust Account	81,905		
		91,953	
			386,205
(iv) Entomology Problems		160,996	
Less contributions from—			
Australian Meat Board	280		
		280	
			160,716
(v) Soils and Irrigation Problems of Irrigation Settlements—			
(a) Citricultural—Research Station, Griffith		40,196	
Less contributions from—			
New South Wales Water Conservation and Irrigation Commission	2,000		
Special Revenue Fund—Griffith Research Station	1,903		
		3,903	
			36,293
(b) Viticultural—Research Station, Merebein		50,066	
Less contributions from—			
Dried Fruits Control Board	1,600		
Mildura Co-op. Fruit Company	250		
Irymple Packing Company	250		
Red Cliffs Co-op. Fruit Company	250		
Aurora Packing Company	250		
Co-op. Dried Fruit Sales Ltd.	250		
Nyah-Woorinen Enquiry Committee	82		
		2,932	
			47,134
			83,427

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* The main items of expenditure under this heading are salaries of the Administrative Staff at the Organization's Head Office; salaries and expenses of officers at the Liaison Offices in London and Washington; staff and upkeep of State Committees; travelling expenses of Head Office Staff; and general office expenditure.

	£	£	£
(vi) Soil Problems	..	..	131,092
(vii) Food Preservation and Transport Problems	..	160,602	
Less contributions from—			
Commonwealth Bank	1,000		
New South Wales Department of Agriculture	1,817		
Metropolitan Meat Industry Commission	500		
Queensland Meat Industry Board	1,275		
Australian Meat Board	500		
Australian Egg Board	750		
Batlow Packing Company	333		
Department of Commerce and Agriculture	5,876		
Apple and Pear Board	15		
Various Contributors	143		
		12,209	
			148,393
(viii) Forest Products Problems	..	231,575	
Less contributions from—			
Australian Paper Manufacturers Ltd.	1,000		
Associated Pulp and Paper Mills Ltd.	1,000		
Australian Newsprint Mills	1,000		
New Zealand Forest Products Ltd.	500		
Department of Territories	2,731		
General Donations	111		
Wooden Case Manufacturers' Association	800		
		7,142	
			224,433
(ix) Mining and Metallurgy	..	25,429	
Less contribution from—			
Australasian Institute of Mining and Metallurgy	500		
	..	500	
			24,929
(x) Radio Research	..	34,784	
Less contributions from—			
Postmaster-General's Department	8,750		
Department of Supply	11,000		
		19,750	
			15.034
(xi) Research Services	..	185,763	
Less contributions from—			
Wool Research Trust Account	5,139		
		5,139	
			180,624
(xii) Industrial Chemistry	..	320,915	
Less contributions from—			
National Gas Association	600		
Cement and Concrete Association	1,500		
Mt. Morgan Ltd. and Mt. Lyell Mining and Railway Co. Ltd.	4,755		
		6,855	
			314,060
(xiii) Fisheries Investigations	..	143,313	
Less contributions from—			
New South Wales Government	250		
		250	
			143.063
(xiv) Mathematical Statistics	..	..	40.540
(xv) National Standards Laboratory	..	..	384.243
(xvi) Tribophysics	..	..	63.347
(xvii) Building Research	..	..	110.280
(xviii) Plant Fibre Research	..	..	32.759
(xix) Radiophysics Research	..	..	248.272
(xx) Metallurgical Research	..	..	9.058
(xxi) Nuclear Energy Research	..	..	28.482
(xxii) Meteorological Physics	..	..	48.490
(xxiii) Dairy Research	..	..	30,879
(xxiv) Wool Textile Research	..	285,656	
Less contributions from—			
Wool Research Trust Account	197,885		
Wool Industry Fund	79,483		
Department of Supply	1,000		
Associated Woollen and Worsted Textile Manufacturers of Australia	754		
		279,122	
			6,534
(xxv) Fuel Research	..	140,185	
Less contribution from—			
Joint Coal Board	15,750		
		15,750	
			124,435
(xxvi) Wildlife Survey	..	64,329	
Less contribution from—			
Wool Research Trust Account	32,165		
		32,165	
			32,164
(xxvii) Land Research and Regional Survey	..	77,856	
Less contribution from—			
Department of National Development	15,559		
Department of Territories	11,128		
		26,687	
			51,169
(xxviii) Genetics	..	25,943	
Less contribution from—			
Wool Research Trust Account	11,751		
		11,751	
			14,192

	£	£	£
(xxix) Miscellaneous—			
(a) Biophysical Research		1,937	
(b) Oenological Research		4,555	
(c) Various		3,499	
		9,991	
Less contributions from—			
Australian Wine Board	2,277		
Science and Industry Endowment Fund	367		
Commonwealth Bank	2,000		
		4,644	
			5,347
(xxx) Unforeseen and Urgent			—
Total of Item (b)—Investigations			3,356,158
(c) *Grants*—			
(i) Research Associations—			
Leather Research Association	6,886		
Bread Research Institute	5,000		
		11,886	
(ii) Overseas Research Studentships		25,392	
		37,278	
Less contributions from—			
Wool Research Trust Account	3,637		
Science and Industry Endowment Fund	1,518		
		5,155	
			32,123
Total Salaries and Contingencies, Investigations and Grants			3,615,121

2. Contributions and Donations.

The following statement shows the receipts and disbursements during the year 1953-54 of the funds provided by outside bodies and recorded in the special account entitled "The Specific Research Fund" (formerly "The Specific Purposes Trust Account")—with the exception of the Wool Industry Fund, details of which appear in Section 4:—

	Receipts 1953-54 and balances brought forward from 1952-53.	Expenditure 1953-54.
	£	£
Commonwealth Bank (Animal Health and Production, Food Preservation and Transport, Genetics, and Farm Mechanization Investigations)	5,593	5,066
Australian Wool Board (Animal Health and Production Investigations—Sheep Research)	1,397	515
Australian Dairy Produce Board (Mastitis Investigations)	2,000	2,000
George Aitken Pastoral Research Trust (Animal Health and Production Investigations)	500	..
W. McIlrath Research Fellowship Fund—Capital (Animal Husbandry Investigations)	25,000	25,000A
W. McIlrath Research Fellowship Fund (Expenses of Fellowship—Animal Husbandry)	1,558	1,558
Australian Meat Board (Cattle Breeding Investigations)	20,586	20,586
Australian Meat Board (Caseous Lymphadenitis Investigations—Animal Health and Production)	412	14
Australian Meat Board (Beef Cattle Research)	20	20B
Australian Meat Board (Bovine Pleuropneumonia Investigations)	90	..
Australian Meat Board (Parasitological Studies of Cattle)	4,000	3,133
Australian Dairy Produce Board (Parasitological Studies of Cattle)	2,000	1,566
Alexander Fraser Memorial Fund (Animal Health and Production Investigations)	600	600C
C. P. P. Fairbairn (Animal Health and Production Investigations—Footrot Control)	30	30
Department of Territories (Importation of Cattle from Pakistan)	426	426D
J. L. Wilson—Studies of Tick Resistance of Cattle (Animal Health and Production Investigations)	100	..
Estate of the late Captain Ian McMaster (Animal Health and Production Investigations)	3,676	3,008E
United Graziers' Association of Queensland—Studies of Tick Resistance of Cattle (Animal Health and Production Investigations)	1,000	..
West Australian Golf Association (Plant Industry Investigations)	51	..
United Graziers' Association of Queensland—Buffalo Fly and Cattle Tick Investigations (Entomology)	172	..
Australian Meat Board—Cattle Tick Investigations (Entomology)	280	280
General Donations (Division of Entomology)	2	..
Burdekin Bequest (Drought Feeding Investigations)	1,700	1,700
N.S.W. Water Conservation and Irrigation Commission (Maintenance of Griffith Research Station)	2,000	2,000
Mildura Co-op. Fruit Co. (Dried Vine Fruits Investigations, Merbein)	250	250
Irymple Packing Co. (Dried Vine Fruits Investigations, Merbein)	250	250
Red Cliffs Co-op. Fruit Co. (Dried Vine Fruits Investigations, Merbein)	250	250
Aurora Packing Company (Dried Vine Fruits Investigations, Merbein)	250	250
Co-op. Dried Fruit Sales Ltd. (Dried Vine Fruits Investigations, Merbein)	250	250
Dried Fruits Control Board (Dried Fruits Investigations)	1,600	1,600
Nyah-Woorinen Dried Fruits Inquiry Committee (Dried Fruits Investigations)	447	82
Australian Dried Fruits Association (Packing House Methods Investigations)	2,000	..

A.—This expenditure relates to the purchase of Commonwealth Inscribed Stock representing balance of the capital of the Fund.

B.—This expenditure is on account of 1952–53.

C.—Includes £300 on account of 1952–53 expenditure and £75 on account of 1951–52 expenditure.

D.—This expenditure is on account of 1952–53.

E.—Includes £593 on account of 1952–53 expenditure.

	Receipts 1953-54 and balances brought forward from 1952-53.	Expenditure 1953-54
	£	£
Australian Meat Board (Meat Investigations)	500	500
Metropolitan Meat Industry Commissioners of New South Wales (Meat Investigations)	500	500
Queensland Meat Industry Board (Meat Investigations)	1,275	1,275
Department of Commerce and Agriculture (Mutton Dehydration Investigations)	6,311	5,876
New South Wales Department of Agriculture (Food Investigations)	1,000	1,000
Vita Food Supply Co. (Food Investigations)	3	
W. Angliss Ltd. (Division of Food Preservation and Transport)	51	
Cottees Passiona Ltd. (Food Investigations)	6	
L. Berger and Sons (Division of Food Preservation and Transport)	50	
Batlow Packing House Co-op. Ltd. (Division of Food Preservation and Transport—Fruit Juice Investigations)	333	333
Various Contributors (Division of Food Preservation and Transport—Fruit Products and Canning Investigations)	472	
Various Contributors (Division of Food Preservation and Transport—Overseas Expenses—R. S. Mitchell)	147	147 F
Australian Egg Board (Division of Food Preservation and Transport—Egg Investigations)	750	750
New South Wales Department of Agriculture—Quick Freezing of Fruit and Vegetables (Division of Food Preservation and Transport)	1,000	817
Australian Paper Manufacturers Ltd. (Paper Pulp Investigations)	1,409	1,000
Australian Newsprint Mills (Paper Pulp Investigations)	1,000	1,000
Associated Pulp and Paper Mills Ltd. (Paper Pulp Investigations)	1,000	1,000
New Zealand Forest Products Ltd. (Paper Pulp Investigations)	500	500
Sundry Contributors (Forest Products Investigations)	2,851	110
Wooden Case Manufacturers (Forest Products Investigations)	865	800
Department of Territories (Development of Pulp and Paper Industry in New Guinea)	2,783	2,731
Australasian Institute of Mining and Metallurgy (Mineragraphic Investigations)	500	500
Postmaster-General's Department (Radio Research)	8,750	8,750
Department of Supply (Radio Research)	11,000	11,000
Drug Houses of Australia (Division of Fisheries—Agar Production)	25	
Miscellaneous Contributors (Division of Industrial Chemistry)	1,275	
Commonwealth Fertilizers and Chemicals (Industrial Chemistry)	300	
Department of Supply (Textile Degradation Investigations)	1,000	1,000
National Gas Association (Gas Investigations — Industrial Chemistry)	733	600
Mt. Morgan Ltd. and Mt. Lyell Mining and Railway Co. Ltd. (Industrial Chemistry—Co-operative Investigations)	5,000	4,755

F.—Includes £4 on account of 1952-53 expenditure.

	Receipts 1953-54 and balances brought forward from 1952-53.	Expenditure 1953-54.
	£	£
New South Wales Government (Fisheries Investigations)	250	250
Russell Pty. Ltd. (Crayfish Investigations (Division of Fisheries)	100	
Department of External Affairs (Handbook of Fish Fauna)		29G
Crayfish Exporters Association of Australia (Crayfish Investigations—Division of Fisheries)	201	
Australian Cement Manufacturers (Cement investigations — Industrial Chemistry/Soils)	1,500	1,500
Apple and Pear Board—Thrips Investigations	77	15
Committee for Dried Fruit Marketing (Section of Meteorological Physics)	340	
Sundry Contributors (Commonwealth Scientific and Industrial Research Organization—Publications)	24	
Wool Wax Report—Royalties	5	..
Science and Industry Endowment Fund	1,885	1,885
Miscellaneous Contributors (Mathematical Instruments Section)	105	
Miscellaneous Contributors (Mineragraphic Investigations)	513	
Wool Scourers, Carbonizers, and Fellmongers Federation of Australia (Wool Textile Research)	3,000	
General Donations (Division of Building Research)	601	
Various Contributors (Foundry Sands Investigations—Division of Industrial Chemistry)	28	
Department of National Development — Kimberley Research Station	1,220	1,046
Australian Dairy Produce Board (Dairy Research Laboratory)	20,000	10,000
Australian Wine Board—Oenological Research	2,303	2,277
Department of Territories (Tobacco Investigations)	1,475	894
Department of Territories (Resources Survey—Papua and New Guinea)	10,827	10,234
Department of National Development (Northern Australia Regional Survey)	15,478	15,478H
Associated Woollen Worsted Textile Manufacturers of Australia (Wool Textile Research)	6,777	754
Joint Coal Board—(Coal Investigations)	17,000	15,750
George Aitken Pastoral Research Trust (Wildlife Survey Section)	1,300	
Special Revenue Fund—"Belmont" Field Station, Rockhampton (Animal Health and Production Investigations)	300	
Special Revenue Fund—National Field Station, "Gi'ruth Plains", Cunnamulla (Animal Health and Production Investigations)	35,942	27,238
Special Reserve Fund—National Field Station, "Gilruth Plains", Cunnamulla (Animal Health and Production Investigations)	15,000	
Special Revenue Fund—Burdekin Bequest (Animal Health and Production Investigations)	1,294	450
Special Revenue Fund—Research Station, Griffith (Citricultural Investigations)	18,525	1,903
	285,949	205,081

G.—Adjustment will be effected in 1954-55.

H.—Includes £964 on account of 1952-53 expenditure.

3. WOOL RESEARCH TRUST ACCOUNT.

A credit balance of £688,064 was brought forward from 1952-53 in the Wool Research Trust Account. A further £440,909 was received during 1953-54, of which amount £390,807 was received from the Department of Commerce and Agriculture, the balance being proceeds of sale of produce. Complete details of transactions during 1953-54 are as follows:—

	£	£	£
Balance in Account, July 1, 1954 ..		..	688,064
Receipts 1953-54.			
Department of Commerce and Agriculture	..	390,807	
Revenue—			
Animal Health and Production—			
Cobram Field Station ..	1,275		
Regional Pastoral Laboratory, Armidale	18,191		
Sheep Biology Laboratory, Prospect	1,401		
Plant Industry—			
"Glen Lossie" Field Station, Kojonup	7,327		
Falkiner Memorial Field Station, Deniliquin ..	14,394		
Biochemistry and General Nutrition — "Glenthorne" Field Station	4,418		
Wool Textile Research Laboratories—			
Textile Laboratory, Geelong ..	2,013		
Biochemistry Laboratory, Melbourne	92		
	49,111		
Proceeds sale of surplus equipment	991	50,102	
Total Receipts 1953-54			440,909
			1,128,973
Expenditure 1953-54.			
Division of Animal Health and Production—			
Parkville—			
Sheep Physiology Investigations —Parkville	5,080		
Sheep Physiology Investigations —Tooradin	1,133		
Fodder Production—Cobram ..	3,487		
McMaster Laboratory—			
Parasitology Investigations— New South Wales	5,769		
Parasitology Investigations— Tasmania and Western Australia	972		
Parasite Physiology and Toxicology	1,695		
Biochemical Investigations ..	2,913		
Physiology of Reproduction ..	2,296		
Dipping and External Parasites	1,032		
Hollerith Equipment ..	3,199		
Veterinary Parasitology Laboratory, Yerrongpilly—			
Sheep Blowfly Investigations ..	6,975		
Sheep Biology Laboratory, Prospect—			
Administrative and General Expenses	32,834		
Fleece Analysis	15,017		
Wool Biology Investigations	23,749		
Strain Trial Investigations ..	7,126		
Regional Pastoral Laboratory, Armidale—			
Parasitology, Agrostology, and Field Investigations ..	57,795	171,072	
Division of Plant Industry—			
Agrostology Investigations ..	74,250		
Mineral Deficiency Studies ..	7,654	81,904	
Research Services—			
Agricultural Research and Extension Liaison	4,305		
Wool Publications	834	5,139	
Division of Industrial Chemistry—			
Expenditure on Wool Textile Research—			
Chemical Physics Investigations	9,658		
Organic Chemistry Investigations	9,160		
Physical Chemistry Investigations	1,336	20,154	
Division of Biochemistry and General Nutrition—			
Biochemical and Nutritional Investigations	32,938	32,938	
Wool Textile Research Laboratories—			
Wool Textile Research	177,731	177,731	
Wildlife Survey Section—			
Wildlife Survey	32,165	32,165	
Animal Genetics Section—			
Animal Genetics Investigations ..	11,751	11,751	
Miscellaneous—			
Overseas Studentships ..	3,637	3,637	
Total C.S.I.R.O. Investigations	..	536,491	
Grants from Wool Research Trust Account to institutions undertaking research in agricultural economics relating to wool production—			
Department of Commerce and Agriculture—			
Bureau of Agricultural Economics	30,137		
Wool Adviser	2,410		
Total Department of Commerce and Agriculture Expenditure	..	32,547	
Total Expenditure 1953-54	..	..	569,038
Balance carried forward to 1954-55	..	..	559,935

4. WOOL INDUSTRY FUND.

A credit balance of £3,495 was brought forward from 1952-53 in the Wool Industry Fund Account. A further £370,000 was received during 1953-54. Expenditure during 1953-54 amounting to £372,399 was incurred as follows:—

	£	£	£
Expenditure by C.S.I.R.O. Divisions and Sections.			
Biological Research—			
Animal Health and Production—			
Sheep Biology Laboratory, Prospect—			
Climate Controlled Building	20,349		
Equipment	11,141		
Development expenditure— fencing, roads, water supply, &c.	7,957	39,447	
Regional Pastoral Laboratory and Chiswick Field Station, Armidale—			
Construction of small buildings and roads and provision of services	6,912		
Improvements	4,424		
Equipment	1,690		
Furnishings for bachelor quarters and cottages ..	780	13,806	53,253
Biochemistry and General Nutrition—			
Glenthorne Experimental Station—			
Sheep yards and units	.	1,716	1,716

	£	£	£
Plant Industry—			
Falkiner Memorial Field Station, Deniliquin—			
Developmental expenditure—fencing, water supply, yards, &c.	..	1,883	
"Glen Lossie" Field Station, Kojonup, Western Australia—			
Developmental expenditure—clearing, fencing, water supply, &c.	..	8,165	
			10,048
Wool Textile Research—			
Biochemistry Laboratory, Melbourne—			
Plant	..	2,044	
Textile Laboratory, Geelong—			
Buildings and site	4,252		
Textile machinery	56,993		
Plant	4,852		
		66,097	
Physics and Engineering Unit, Sydney—			
Plant	..	11,343	
			79,484
Expenditure by Department of Works on C.S.I.R.O. Buildings.			
Biological Research—			
Animal Health and Production—			
Sheep Biology Laboratory, Prospect—			
Animal house No. 2	2,551		
Two prefabricated buildings	28,891		
Animal house No. 1	29,887		
Main administrative building	608		
Climate controlled building	9,443		
		71,380	
Regional Pastoral Laboratory and Chiswick Field Station, Armidale—			
Residence for Officer-in-charge	..	584	
			71,964
Plant Industry—			
Head-quarters, Agrostology Section, Canberra—			
Agrostology and Pasture Chemistry prefabrications	..	12,568	
Western Australian Investigations—			
Regional Laboratory, Perth	18,447		
Two staff cottages, Kojonup	1,462		
		19,909	
Regional Pastoral Laboratory and Falkiner Memorial Field Station, Deniliquin—			
Staff cottages	404		
Two pairs of houses	3,072		
Bachelor quarters	2,334		
		5,810	
			38,287
Biochemistry and General Nutrition—			
Glenthorne Experimental Station—			
Field laboratory	3,110		
Hay and chaff shed	480		
		3,590	
			3,590
Minor Works—			
New South Wales	6,826		
Victoria	1,294		
Western Australia	7		
		8,127	
			8,127
Wool Textile Research—			
Biochemistry Laboratory, Melbourne—			
Laboratory building	1,362		
		1,362	
Textile Laboratory, Geelong—			
Laboratory and six cottages	53,616		
Development of site	1,396		
		55,012	
Minor Works—			
New South Wales	297		
Victoria	837		
		1,134	
			57,508

	£	£	£
Grants from Wool Industry Fund for Extra-mural Co-operative Wool Research.			
Biological Projects—			
Victoria—			
Melbourne University—			
Electrolyte physiology studies	3,000		
Department of Lands and Survey—			
Rabbit Investigations	11,500		
		14,500	
Western Australia—			
Institute of Agriculture—			
Ruminal flora studies	3,145		
Genetic studies	1,100		
Department of Agriculture and Institute of Agriculture—			
Clover infertility investigations	2,280		
		6,525	
South Australia—			
Roseworthy Agricultural College—			
Progeny testing	4,135		
Waite Institute—			
Agrostology, weeds, and entomology	4,000		
		8,135	
Queensland—			
Department of Agriculture and Stock—			
Fertility and neo-natal mortality	850		
Progeny testing and wool metrology	800		
Copper deficiency	350		
University of Queensland—			
Sheep physiology	2,400		
Acclimatization studies	400		
Small laboratory	1,100		
		5,500	
New South Wales—			
University of Technology—			
Wool clip analysis	3,830		
University of Sydney—			
Animal physiology investigations	1,750		
Department of Agriculture—			
Disorder metabolism	480		
Conservation Authority of New South Wales—			
Ecological studies	2,500		
		8,560	
			43,220
Wool Textile Research—			
Gordon Institute of Technology—			
Wool textile investigations	3,570		
Wool Industries Research Association, United Kingdom	1,254		
		4,824	
			4,824
Additional Items Sponsored by C.S.I.R.O.			
Footrot school for veterinary officers	286		
Expenses in connexion with Wool Textile Conference, 1955	92		
		378	
			378
			372,399

5. Divisional Revenue.

The following amounts were earned by Divisions and Sections apart from the Special and Wool revenue included under Sections 2 and 3 respectively:—

	£	£
General Revenue.		
Division of Animal Health and Production—		
Sale of Contagious Pleuropneumonia Vaccine	6,972	
Mastitis Investigations	3,918	
Parkville Laboratory	384	
Toxaemic Jaundice Investigations, Parkville, Victoria	207	
Oestrus Experiments	1,395	
Poultry Breeding Investigations	11,331	
Contagious Pleuropneumonia Investigations	355	
Tooradin Field Station	5	
Bacteriological Investigations	21	
Parasitological Investigations	1,657	

	£	£
McMaster Field Station Revenue	3,666	
Veterinary Parasitology Laboratory ..	1,174	
Amberley Field Station, Queensland ..	218	
Division of Plant Industry—		
Plant Industry Investigations, Canberra ..	4,192	
Stanthorpe Field Station	668	
Division of Entomology—		
Entomological Investigations	49	
Merbein Research Station Revenue	4,730	
Division of Food Preservation and Transport Revenue	201	
Division of Forest Products	159	
Ore-dressing Investigations	584	
Central Experimental Workshops	18	
Division of Industrial Chemistry—		
Industrial Chemistry Investigations ..	3	
Microanalysis Investigations	2,947	
Division of Fisheries—		
Fisheries Investigations	15	
Sale of Pearlshell	281	
Division of Metrology	4,668	
Division of Electrotechnology	763	
Division of Physics	740	
Division of Building Research	21	
Meteorological Physics Section	15	
Land Research and Regional Survey, Katherine	1,287	
Fuel Research Section	2	
Total		52,646

The above sum was paid to the credit of the Trust Fund Science and Industry Account during 1953-54 and consequently reduced the requirements from Treasury sources by that amount.

6. Works Projects (under Control of C.S.I.R.O.).

Expenditure on works projects from funds made available directly to C.S.I.R.O. by the Treasury is as follows:—

	£	£
Homebush Laboratory	1,963	
		1,963

7. Miscellaneous Services.

	£
Contribution to Commonwealth Agricultural Bureaux	38,401
Grant to Standards Association of Australia ..	40,000
Grant to Australian National Research Council ..	1,500
Contribution to Chair of Aeronautics at University of Sydney (establishment and maintenance) ..	5,000
Grant to National Association of Testing Authorities	8,400
Australian and New Zealand Association for the Advancement of Science	3,500
Pan Indian Ocean Science Congress	600
Eighth Pacific Science Congress	870
	98,271

XXXVI. ACKNOWLEDGMENTS.

In various sections of this Report reference has been made as in previous years to the valuable assistance afforded by many State Departments, Universities, and other organizations and individuals. The Organization desires to express its gratitude for the help given by these bodies and persons in providing laboratory accommodation and other facilities and in many other ways. The Organization also wishes to acknowledge the assistance it has received from its Committees, the members of which have placed their knowledge and experience so freely at its disposal.

I. CLUNIES ROSS, Chairman
F. W. G. WHITE
S. H. BASTOW
H. G. GOODES
A. B. RITCHIE

Executive.

19th October, 1954.

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